Bedford Institute of Oceanography 2000

Pictou Boats

Silverberg

Canada

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Cover artwork "Pictou Boats"

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INTRODUCTION

It is with great pleasure that we introduce the BIO review for the calendar year 2000, providing an overview of the many activities at the Bedford Institute of Oceanography (BIO). BIO is a modern oceanographic research facility, established in 1962 by the Federal Government of Canada and is located on the shores of the Bedford Basin in Dartmouth, Nova Scotia. Over the last four decades it has grown to become Canada's largest centre for ocean research. The Institute performs targeted research, mandated by the Canadian government, to provide advice and support to government decision making on a broad range of ocean issues, including sovereignty, defence, environmental protection, health and safety, fisheries and natural resources and undertakes environmental and oceans management and planning.

Bordered by three oceans, Canada has a 240,000 km coastline, the longest of any country in the world. Its continental shelf represents an area about 40% the size of the Canadian landmass. The dimensions of our oceans space has had a profound influence on our culture and history. In and under the oceans, enormous quantities of natural resources reside in the water column or lie buried in the bedrock; these include stocks of fish, shell fish and marine plants, oil and natural gas and mineral resources. This can mean economic sustainability for generations of Canadians. Against this background, Canada must collect information about all aspects of its ocean resources; this information is vital for land-use and coastal planning, ocean management and reducing risk from natural and anthropogenic hazards.

Oceanography is a multi-disciplinary research field, involving geological, physical, chemical and biological research disciplines. To solve problems related to the oceans, BIO houses over 400 scientists, engineers, technicians, natural resource and environmental managers, and support staff from a variety of different disciplines. Currently, four federal departments are located at BIO: Fisheries and Oceans Canada (DFO), Natural Resources Canada (NRCan), Environment Canada (EC) and the Department of National Defence (DND).

DFO is represented by four divisions within its Science Sector, the Canadian Hydrographic Service (CHS), and by three divisions of the Oceans Sector. Together they provide scientific knowledge and advice on a wide variety of issues related to climate, oceans, the environment, marine and diadromous fish, mammals, shell fish and plants, and carry out oceans and environmental management and planning. NRCan is represented by the Geological Survey of Canada (Atlantic). It has become Canada's principal marine geoscience facility and its scientific research expertise focuses on marine and petroleum geology, geophysics, geochemistry and geotechnology. GSC Atlantic is also the source of integrated knowledge and advice on Canada's coastal and offshore land mass. DND supports its ocean surveillance activities through the Maritime Forces Atlantic's Route Survey Office located at BIO. In cooperation with CHS and GSC Atlantic, surveys of areas of the sea floor of specific interest to DND are conducted. The Shellfish Section of Environment Canada conducts sanitary and water quality surveys and analyzes the samples at the microbiology laboratory at BIO in support of the Canadian Shellfish Sanitation Program.

This BIO review will highlight some of the ongoing research activities at the Institute as well as some of the other activities dealing with the management of the oceans.

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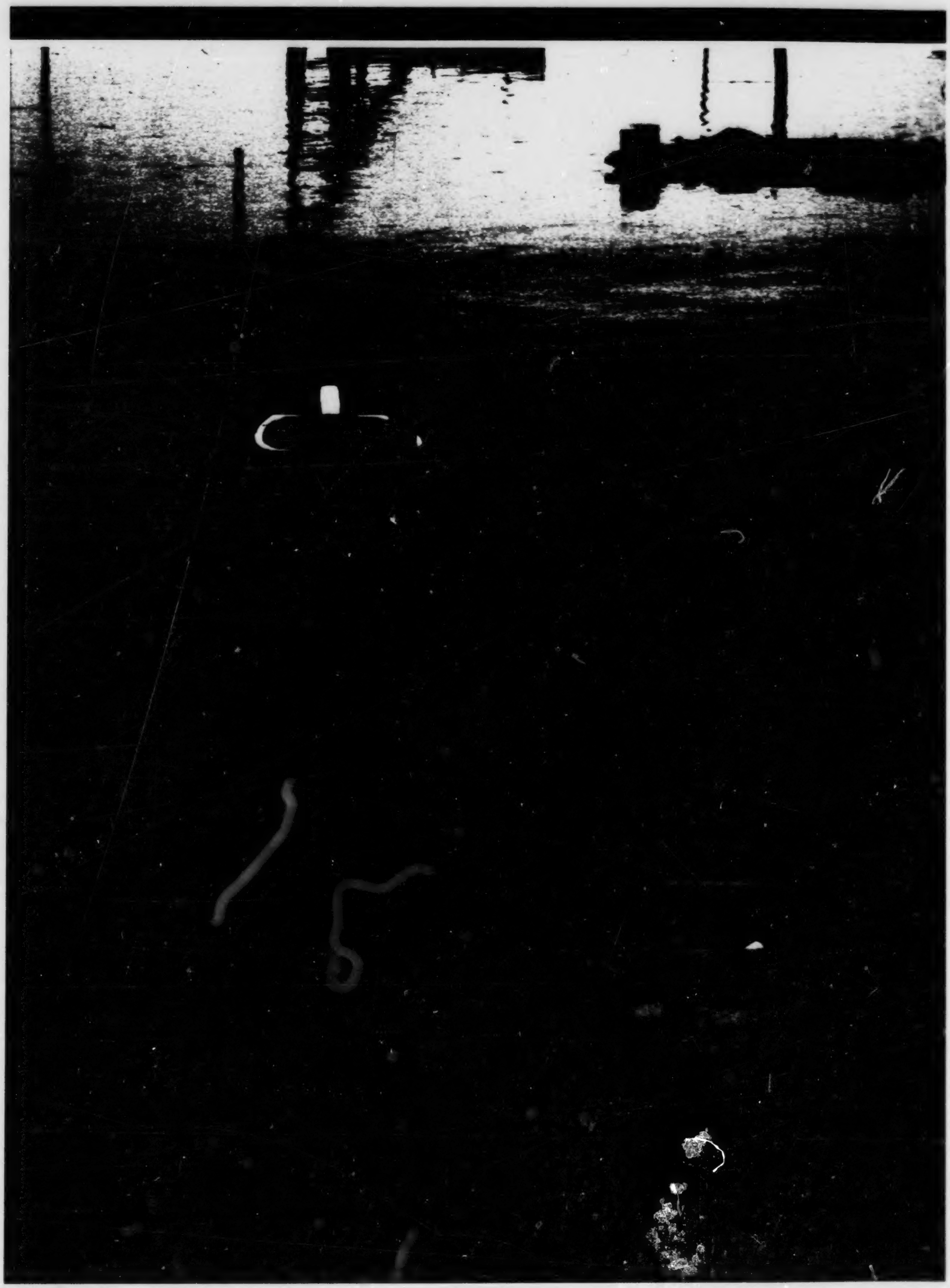


Table of Contents

Highlights of the Year 2000 5

Science Activities

Geological Survey of Canada (Atlantic)

Integrating Stratigraphy and Palynology in the Glenelg Natural Gas Field, Offshore Nova Scotia *R. Andrew MacRae* 10
The Scotian Slope: The Unknown Frontier for Hydrocarbon Exploration - *David J. W. Piper* 12
Tectonic and Hydrocarbon Implications for Davis Strait from Newly Compiled Geophysical Data *Gordon Oakey, Ruth Jackson, and Richard Whittaker* 13

Canadian Hydrographic Service

The Canadian Hydrographic Service Source Database - *Steve Forbes, Robert Burke, and Herman Varma* 15
Nautical Charting - *Richard MacDougall* 16

Ocean Sciences

Improving the Skill of the Canadian Search-and-Rescue Planning System (CANSARP) *Peter C. Smith, Don Lawrence, Josko Bobanovic, and Keith R. Thompson* 17
Atlantic Zonal Monitoring Program - *Michel Mitchell* 18
Monitoring Reveals Significant Changes in the Ocean Climate on the Scotian Shelf and in the Gulf of Maine - *Ken Drinkwater and Charles Tang* 20
Towards Predictive Modelling of Larval Survival and Recruitment of Browns Bank Haddock *David Brickman, Charles G. Hannah, Nancy L. Shackell, Kenneth T. Frank, and John W. Loder* 22

Marine Environmental Sciences

Fate and Effects of Marine Contaminants - *Phil Yeats, Peter Cranford, and Simon Courtenay* 24
Canadian Imaging and Sampling Technology for Studying Marine Benthic Habitat and Biological Communities - *Don Gordon Jr., Ellen Kenchington, Kent Gilkinson, David McKeown, George Steeves, Mark Chin-Yee, Peter Vass, Kelly Bentham, Kee Muschenheim, Tim Milligan, Cynthia Bourbonnais, and Kevin MacIsaac* 26

Biological Sciences

Shark Research Program - *Steven Campana* 28
Traffic Light Indicators - *Robert Mohn, Jerry Black, and Peter Koeller* 30
Comparative Dynamics of Exploited Ecosystems in the Northwest Atlantic: Ecosystem Modelling of the Eastern Scotian Shelf Shedding New Light on Mortality - *Alida Bundy and Caihong Fu* 31
Lobster Fisheries Management - *Robert Miller* 32
CLAWS Contributions: Focus on Benthic Field Studies - *John Tremblay and Peter Lawton* 33
Regional Declines in Atlantic Salmon Abundance - *Larry Marshall and Peter Amiro, in collaboration with Eric Verspoor* 34
Acid Rain and Atlanic Salmon - *Peter Amiro* 36
Research Voyages - *David L. McKeown* 38

Cross Cutting Issues

Maritime Aquatic Species at Risk Act Office - *John Loch* 40
SeaMap - Discovering Canada's Next Frontier - *Richard MacDougall, Richard Pickrill, Jim Bradford, and Don Gordon* 41
Climate Change and Variability - *Allyn Clarke* 42
Coastal Impacts of Climate Change in Prince Edward Island - *Donald L. Forbes, Martha McCulloch, Richard Chagnon, Kelly MacDonald, Gavin Manson, Charles O'Reilly, Georges Parkes, and Keith Thompson* 44

Precise Geoid Determination for Geo-Referencing and Oceanography - GEOIDE (Geomatics for Informed Decisions) Project No. 10 - *Michael G. Sideris, Keith R. Thompson, Petr Vanícek, Spiros Pagiatakis, Charles O'Reilly, and Ross Hendry* 45

Resource Management Highlights

Oceans and Coastal Management - *Erin Rankin* 47
Habitat Management Division - *Jim Ross* 48
Provision of Science to Our Clients - the Regional Advisory Process or RAP - *Robert N. O'Boyle* 49
Environment Canada at BIO - *Diane Tremblay* 50

Technical Support Highlights

BIO has a Presence on the Web: http://www.bio.gc.ca - *Paul Boudreau and Joni Henderson* 51
Informatics - *Gary Collins* 52
Knowledge and Information Management at GSC Atlantic - *Mark Williamson and Phil Moir* 53
Bedford Institute of Oceanography (BIO) Archives - *Anna Fiander* 54
GSC Atlantic Technical Support Group 54
Curation Activities at GSC Atlantic - *Iris Hardy* 55
Outreach at BIO (Natural Resources Canada and Fisheries and Oceans Canada) - *Jennifer L. Bates, Rob Fensome, Joni Henderson, John Shimeld, and Graham Williams* 56
DND Route Survey - *Jim Bradford* 57
DFO Technical Services 57
Charity at Bedford Institute of Oceanography - *Shelley Armsworthy* 58
Staff 59

Other Programs

International Ocean Colour Coordinating Group (IOCCG) - *Venetia Stuart* 60
Partnership for Observation of the Global Oceans (POGO) - *Shubha Sathyendranath* 61
Bedford Institute of Oceanography - Oceans Association - *Dale Buckley* 61
Fishermen and Scientists Research Society - *Kees Zwanenburg* 62

Financial and Human Resources

Financial Information 64
At BIO in 2000 66
In Memoriam 72

Publications and Products

Publications 2000 74
Products 2000 88

Highlights of the Year 2000

As elsewhere around the world, the year 2000 at BIO began with some trepidation with respect to our computer systems and facilities. While most of us celebrated the millennium event, the computer group and facilities staff were reviewing contingency plans in the Institute as the clock struck midnight. Due to their diligence, the transition was a smooth one. The Y2K team is thanked for a job well done. A side benefit to the transition activities was a significant investment in improved documentation and accessibility of data sets.

New initiatives

The Oceans Act, passed in 1997, continued to have an influence on DFO's priorities during 2000. Under the Act, DFO has the responsibility to lead development of a Canadian Oceans Strategy based on three principles, the precautionary approach, integrated management, and sustainable development. A key component of Canada's Oceans Management Strategy is the development of oceans management plans within which the aggregate ocean use activities will achieve broad conservation objectives, which are in the process of being defined at the national level. BIO scientists were leaders in the preparation of a framework for the practical application of ecosystem-based management that has been accepted as a national model by DFO. Two high profile initiatives under the Oceans Act umbrella are the Eastern Scotian Shelf Integrated Management (ESSIM) initiative, and the evaluation of the Gully Area of Interest (which is within the Eastern Scotian Shelf) as a Marine Protected Area.

The Government of Canada continued its special funding for projects on climate change. During the year 2000, several projects were funded under the Climate Change Action Fund (CCAF). Several scientists at BIO are involved in those projects, focusing largely on the potential impacts of sea level rise on the coastal regions of Atlantic Canada (more details are in Cross Cutting Issues).

The federal government has focussed on endangered species during 2000, with the introduction of the draft Species at Risk Act to Parliament. In preparation for the enhanced focus on marine endangered species, a new organizational unit was formed at BIO in 2000. It is entitled the Marine Aquatic Species at Risk Office (MASARO). The initial priorities have been on the northern right whale, leatherback turtles (in partnership with Dalhousie University), harbour porpoise, Atlantic whitefish, and inner Bay of Fundy Atlantic salmon. Further details are described under Cross Cutting Issues.

The Seabed Resource Mapping Program (SeaMap) is a visionary, cross-Departmental initiative to provide an important part of the knowledge base for a sustainable ocean sector of the economy. Three of the federal departments at BIO (DFO, NRCan and DND) have taken the lead in developing the concept and proposal to map the overall seafloor within Canada's Exclusive Economic Zone (EEZ). SeaMap planning workshops were conducted across Canada and attended by representatives from federal departments, ocean user industries, ocean mapping firms, other service industries, provincial government departments, universities, non-government organizations, and environmental groups. This proposal is described in more detail later in the report.

The Department of Fisheries and Oceans has been designated as the lead federal agency for aquaculture under the Federal Aquaculture Development Strategy. To show its commitment in fulfilling this role, the Department announced a $75 million Program for Sustainable Aquaculture, with funding that will increase knowledge for decision-making through greater science, research and development; strengthen measures to protect human health through an enhanced shellfish inspection program; and make the legislative and regulatory framework more responsive to public and industry needs.

The Maritimes Region of Fisheries and Oceans has established an Aquaculture Coordination Office at BIO, which will be the regional focus for the delivery of this commitment to further enhance public and industry confidence in the aquaculture sector. Currently the office is focussing on: implementing improvements to the regulatory framework and the site approval process, updating the framework for operational decision-making to ensure front-line staff have the direction and the information they need to make sound and consistent decisions, and working with the provinces and industry to establish mechanisms for co-operation and harmonization.

Partnerships

Dr. Tom Traves, President, Dalhousie University (left) and Dr. John Davis, DFO, ADM Science (right) who signed a Memorandum of Understanding at an event held at the Bedford Institute of Oceanography on 15 September, 2000.

The federal government has included in its present priorities an increasing role for partnerships in achieving its mandate. To this end, BIO has strengthened working relationships with universities in the Maritime Provinces, the First Nations, other federal and provincial agencies, the private sector, and non- government organizations (NGOs).

Under the Canadian Biotechnology Strategy, a joint project with the University of Prince Edward Island, the University of New Brunswick, and Dalhousie University was initiated on the population genetics of lobster, herring and haddock. A Memorandum of Understanding was signed with Dalhousie University to facilitate collaboration on research on marine conservation genetics. A DFO Chair in Fisheries Resource Conservation Genetics and Biotechnology has been established at Dalhousie. This latter initiative is part of a broader focus initiated by BIO and Dalhousie scientists on biodiversity issues. A Centre for Marine Biodiversity has been formed with membership from several DFO laboratories, Dalhousie University, and the Atlantic Reference Centre of the Huntsman Marine Science Centre in St. Andrews. A second centre has been formed in 2000, the Centre for Marine Environmental Prediction. The Oceanography Department at Dalhousie University is the lead, with participation of several BIO physical oceanographers. A major objective of the centre is to provide oceanographic data products from ocean and atmospheric monitoring programs of use to ocean industries and society. Under the Census of Marine Life initiative of the Sloan Foundation, BIO and the University of Southern California initiated a partnership on data integration and visualization in the Gulf of Maine Area (the area for a pilot project for the Census).

An important principle related to development of Canada's Oceans Strategy is collaboration among federal and provincial jurisdictions, First Nations and other interested parties. A Memorandum of Understanding between federal and provincial departments of Environment and Fisheries focuses on federal/provincial collaboration in support of community-based sustainability initiatives. An integrated management initiative in the Bras d'Or Lakes is currently the primary focus under this MOU.

Another Memorandum of Understanding has been signed with the First Nations in the Bras d'Or Lakes area of Cape Breton to enhance research in support of integrated management of this unique marine ecosystem. As part of the memorandum, DFO is providing a research vessel for five years, starting in 2000. BIO has formed a multidisciplinary team to coordinate the research activities and raise funds for research. Fieldwork during 2000 focussed on habitat mapping (using multi-beam sonar and laser infrared detection and ranging [LIDAR]) as well as measurement of circulation and mixing.

Additional work has been initiated with First Nations to improve the sampling of their lobster fisheries that have expanded following the 1999 Supreme Court Marshall decision which gave Aboriginal peoples greater access to fisheries.

A major challenge for BIO is to compare impacts of diverse lobster fisheries and regulatory controls in a common currency of fishing mortality. To this end, the Gulf of Maine region has been defined as a lobster production area, within which new approaches are being developed with the fishing industry and First Nations to achieve the enhanced conservation objectives defined by the former DFO Minister Anderson in 1998.

Partnerships have also been expanded with the fishing industry. For example, the offshore sector funded a study of the potential mixing of cod from different spawning areas in the Laurentian Channel during the winter months. The study involves the electronic tagging of cod, and subsequent monitoring of their movements by a sonic receiver network placed on the sea floor off Cape Breton.

A partnership with the Fundy Marine Resource Centre has resulted in improved capacity for local community associations to use GIS-based mapping techniques for coastal planning. Through a partnership with the Integrated Coastal Planning Project at Daltech, a coastal planning course has been developed and is being delivered to professional land use planners.

In a unique partnership between GSC Atlantic, the Canadian Hydrographic Service and the Offshore Scallop Producers of Nova Scotia, seafloor mapping technology has been applied to the production of digital maps of surface sediments and fisheries habitat on the highly productive scallop grounds of Browns, Georges and German banks. Five separate "layers" of information are exported to electronic navigation systems for use by the offshore fishing fleet. Access to this new technology is expected to reduce environmental impacts and increase economic benefits for the scallop industry.

In a research partnership between GSC Atlantic, five petroleum companies, and one fishing company, multibeam bathymetric surveys of the Scotian Slope and follow-up seismic and bottom sampling programs have been successfully completed. The project arose out of GSC's ongoing interest in providing a regional framework of slope stability for hazard assessment and the petroleum industry's need for information for safe exploration planning. The resulting data set, covering more than 20,000 sq. km, represents the largest multibeam survey completed in Canadian waters.

GSC Atlantic is responding to a fast-growing demand for marine geoscience research related to hydrocarbon exploration and development off Canada's East Coast. One result of the research is a better understanding of seabed constraints to the installation of offshore production facilities. On Sable Island Bank, a collaborative program with industry is documenting sediment scour below gas production facilities at the peak of severe winter storms. In the new lease blocks of the Scotian Slope, collaborative research is providing information about trigger mechanisms for slope sediment failures that are of major concern to the siting and operation of drilling platforms.

The Natural Sciences and Engineering Research Council (NSERC) announced a major funding award for a multi-agency program to investigate Canada's East Coast offshore margins. Led by Dalhousie University, other partners include GSC Atlantic, Memorial University, the University of Calgary, and British, Danish and U.S. research groups. The award forms the cornerstone of the fledgling initiative, MARIPROBE, which will develop an understanding of the origin and evolution of Canada's extensive and resource-rich continental margins. This initiative will ensure continuation of Canada's international leadership for this type of investigation.

GSC Atlantic completed a detailed aerial video survey along the Nova Scotian shore of the Northumberland Strait. The survey was undertaken in funding partnership with the Pictou Harbour Environmental Protection Project, a community-based organization, under the Environment Canada, Atlantic Coastal Action Program (ACAP). The focus of the survey was on Pictou County and in particular, the Pictou Harbour watershed. The video has a variety of uses but was collected primarily for mapping the physical character of the shoreline and for monitoring natural and human-induced changes.

A major DFO partnership during 2000 with non-governmental organizations involved species at risk, in particular the northern right whale. The World Wildlife Fund and BIO completed the Recovery Plan for this endangered mammal, and the implementation process was initiated at the Institute in September during a meeting with a broad range of interested parties. In addition, BIO and East Coast Ecosystems carried out the annual survey of right whale distribution in the summer feeding area off southwest Nova Scotia.

Workshops and conferences at BIO

The oil and gas industry organized a highly successful workshop at BIO in March on "Understanding Environmental Effects of Offshore Hydrocarbon Development." The technical report, available from DFO documenting the proceedings, is expected to become a landmark document.

Environment Canada and DFO co-hosted a workshop at BIO in April to evaluate the potential impacts of fishing activities in northern waters on seabird populations. The results of the workshop are being used to modify Canada's fishing practices in relation to our international sustainability obligations.

The Habitat Management Division of the Oceans and Environment Branch in partnership with the Halifax Regional Municipality sponsored and organized a major workshop entitled *Preserving the Environment of the Halifax Harbour*. This involved participants from all municipal, provincial and federal departments with regulatory and scientific responsibilities for Halifax Harbour and its watershed. The various agencies examined and discussed individual mandates and possible interactions. The proceedings have been published and include a Project Activity - Administrative Stakeholder matrix.

An Eastern Scotian Shelf Integrated Management (ESSIM) initiative workshop was held at BIO with major components of the meeting directed towards defining ecosystem objectives of integrated management and discussing monitoring needs for future ocean management activities.

International

BIO contributed to a number of international oceans activities in 2000, including the International Council for the Exploration of the Sea (ICES) meetings on cod and climate change held at BIO in May. The office for the Partnership for Ocean Global Observations (POGO) was established at BIO. A major role of POGO is to provide support for deep-ocean research and monitoring activities on a global scale. A workshop of Living Marine Resources – Global Oceans Observing System (LMR-GOOS) was held in March to define Canada's contribution to the living marine resources component of GOOS. The workshop focussed on the definition of monitoring requirements for indices supporting ecosystem objectives of integrated oceans management.

2000 Huntsman Award winner Dr. William Jenkins and Dr. Howard Alper, President, Academy of Science, Royal Society of Canada.

GSC Atlantic is part of a Canadian consortium in the International Marine Global Change Study (IMAGES) investigating climate records on the Scotian Margin and in the Labrador Sea. These records are used in computer models that forecast long-term climate change in Canada and allow us to estimate changes from continued global warming.

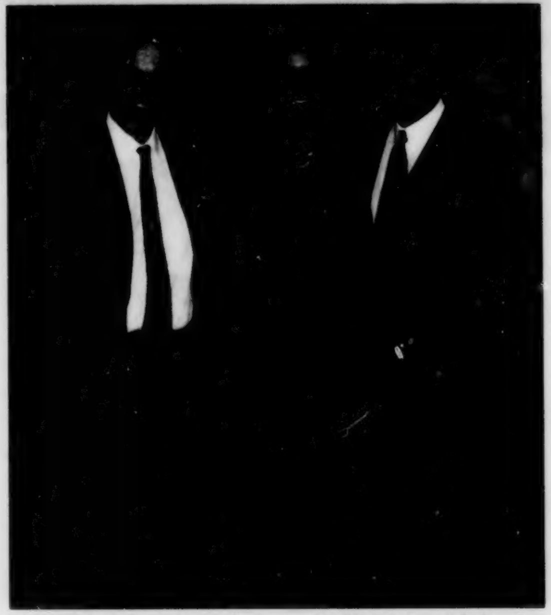
GSC Atlantic took part in international meetings to explore collaborative projects involving the Ocean Drilling Program (ODP) and the petroleum industry. Eight proposals to drill on continental margins worldwide were put forward by industry; projects on the Grand Banks and in the Scotian Basin received a high priority. Both projects would add significantly to the geoscience community's understanding of the history and architecture of the thick, oil-bearing sedimentary deposits along Canada's East Coast.

A Canadian consortium, which includes GSC Atlantic and CHS, was awarded a three-year contract to act as the external scientific consultant for a project by the Geological Survey of Ireland to map the offshore region of Ireland. The Canadian consortium designed the mapping survey, provided equipment specifications, and recommend training requirements. The awarding of this consulting contract underscores Canada's excellent capability in offshore mapping.

GSC Atlantic signed a five-year agreement with the Uruguayan Department of Defence, under which the two organizations will collaborate and exchange marine geoscience knowledge and information. It is anticipated that this agreement will help Canadian geoscience businesses to provide products and services that can support sustainable economic growth in Uruguay's marine sector.

Challenges – facilities and ships

It is important to indicate that the year 2000 has not been without difficulties. Research vessel support requires urgent attention; shortfalls in funding have resulted in reduced vessel time at sea. Uncertainties make it challenging to plan national contributions to international programs and partnerships with universities or national/zonal initiatives. BIO itself is in the process of renovation, but funding has been intermittent. The Institute and vessels need significant new investment.



Michael Sinclair, Joni Henderson, and DFO Minister Dhaliwal during the Minister's visit to BIO.

Awards and honours

There were a number of special awards and honours during 2000 that are noteworthy. Professor William Jenkins was awarded the Huntsman Medal for outstanding contributions in physical oceanography. The Fishermen and Scientists Research Society was the first recipient of the Deputy Minister's award for partners. The award was presented to the Society's executive at BIO by DFO Minister Dhaliwal in March. Several high school students were given awards for their artwork in celebration of Oceans Day. The theme for 2000 was the "Mystery of the Oceans." Tim Hall won the DM's Prix d'Excellence for his outstanding contribution in working with communities on coastal zone management. Sharon Morgan won the DM's Prix d'Excellence for her special contribution to managing the highly successful Science and Technology Youth Internships Program (19 interns were hired through BIO in 2000). Department of National Defence employee, Julie Daoust was the navel reservist selected from across Canada to be one of the eight pall bearers representing the Canadian Forces during the Return of the Unknown Soldier.

In closing, it is fitting to note that BIO also focussed on its history during 2000. The Ron Trites Boardroom was officially unveiled in the presence of members of his family. Dr. Trites had been an influential physical oceanographic researcher during the founding years of the Institute and was the "staff choice" for naming of this new boardroom. All the buildings in the Institute have new signs explaining the origin of their names (Van Steenburgh, Polaris, Murray, Holland, Strickland, and Vulcan). Efforts have been directed towards archiving papers, equipment, and photographs with the help of the BIO Oceans Association.

Visitors

Distinguished visitors included Minister Dhaliwal (Fisheries and Oceans), Mel Cappe, (the Clerk of the Privy Council), Ólafur Ragnar Grimsson, and Ms. Siv Fridleifsdottir (the President and Minister of Environment of Iceland respectively). During the Huntsman Award presentation, BIO also welcomed the new Lieutenant-Governor of Nova Scotia, the Honourable Myra Freeman, and the new President of the Academy of Science of the Royal Society of Canada, Dr. Howard Alper.

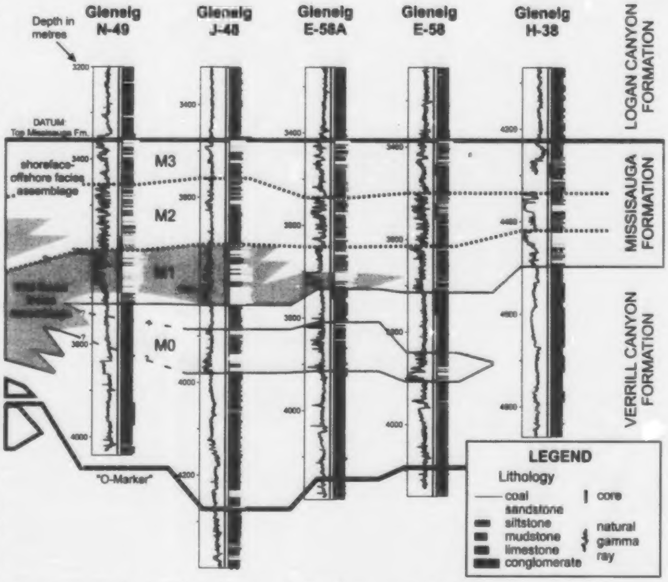
Michael Sinclair welcomes President Ólafur Ragnar Grimsson, of Iceland, to BIO.

SCIENCE ACTIVITIES

Geological Survey of Canada (Atlantic)

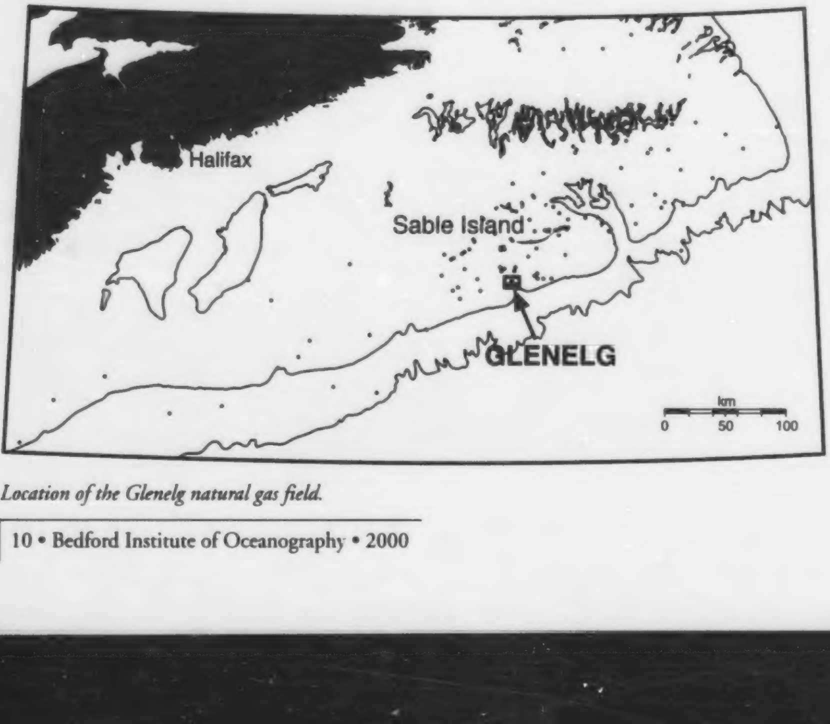
Integrating Stratigraphy and Palynology in the Glenelg Natural Gas Field, Offshore Nova Scotia – R. Andrew MacRae

Nova Scotia is experiencing a boom in offshore hydrocarbon exploration and development, thanks to new discoveries and investment by industry in the infrastructure to produce natural gas. Most of the deposits are found at depths of three or more kilometres in the thick wedge of sediments that have accumulated along the margin since the Atlantic Ocean opened. Natural gas is found in these rocks for two main reasons: 1) because the sediments were buried deep enough to heat the dead, microscopic plant material contained within them until they gave off natural gas and smaller amounts of oil, and 2) because after these hydrocarbons were expelled from their source rocks, they encountered porous sandstones, called reservoirs. These were overlain by impermeable rocks, such as mudstones, that discouraged further migration. These processes, in some sense, are a factor in all hydrocarbon occurrences, and are known respectively as the source and trap. To explore and produce hydrocarbons successfully, it is necessary to understand the history and details of all the processes involved.



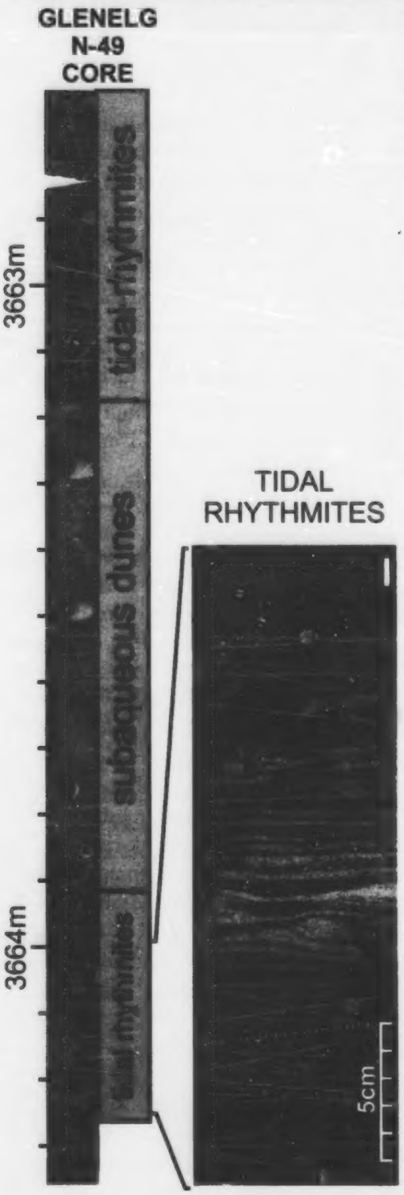
Summary of the stratigraphic correlation between wells of the Glenelg field, showing paleoenvironments.

The Glenelg field, one of five natural gas deposits currently being developed, has been studied to understand the conditions under which its sedimentary rocks were deposited. Many questions exist, such as: what controlled the distribution of the sediments that are now gas reservoirs? are some sandstone types (facies) better reservoirs than others, and why? what accounted for the vertical and lateral variation in the facies over time? is it possible to predict from this pattern what might be found in other areas? These questions are being addressed by studying the physical structures found within the rocks, and by studying trace fossils and microscopic fossils known as palynomorphs (fossil pollen, spores, and single-celled "algae" known as dinoflagellates). Sedimentology and paleontology is a powerful combination, because they provide a sensitive indication of the depositional environment at the time, as well as the relative age of the rocks. At Glenelg, the rocks are mid Early Cretaceous age, formed about 120 to 130 million years ago — the time of the dinosaurs.



Location of the Glenelg natural gas field.

The primary data from Glenelg are drill cores — cylindrical segments of rock ex-



An example of tidal rhythmites in a Glenelg drill core, more than three kilometers beneath the surface.

tracted during drilling. These intact rock samples provide the calibration for other techniques, such as in-hole measurements of various rock properties, the interpretation of chips of rock produced during the drilling, and seismic (sound) profiles. Data at Glenelg reveal alternating sandstone and mudstone beds of the upper Mississauga Formation — a widespread formation deposited by an ancient river delta. The delta system alternately built out and receded at Glenelg at least four times in this interval. The upper two phases did not extend as far as the previous ones.

Three key observations support this interpretation:

1) Several erosive-based, fining-upward successions of sandstone grading to mudstone, capped by coal and fossil plant roots, occur within the second phase. Each succession corresponds in detail to the classic pattern seen for migrating and infilling river channels in modern deltas, showing that the river system reached this far and was intermittently land.

2) In the upper two phases, there are no indications of river channel development, and the succession coarsens upwards, culminating in the fine, well-sorted, burrowed sandstones typical of deposition in a wave-dominated environment in front of a beach (the shoreface).

3) The palynomorphs show a cyclic pattern that alternates between intervals dominated by terrestrial pollen and spores, and intervals with greater numbers of marine dinoflagellates.

Although the data are consistent with a delta system, certain details imply a special setting for the river channels. Most freshwater river channels are characterised by an impoverished and distinctive trace fossil assemblage. Those at Glenelg are almost devoid of trace fossils in their base. Towards the top, where conditions are inferred to be shallower and where currents were weaker, the trace fossils present are more typical of stressed marine or brackish water environments, and root traces immediately below the coals occur in laminated mudstones similar to intertidal mud flats that occur in places like the Bay of Fundy. Deeper within the channel infill successions are metre-thick, medium to coarse sandstones, commonly with crossbedding formed by underwater dunes of several metres wavelength. This implies a strong current to move the sediment and generate the dunes. The dunes often alternate with millimetre to centimetre, rhythmically-interbedded sandstones and mudstones that imply weaker, but consistently-fluctuating, currents. Although alternations between such sediment types and current strengths are expected in any river system, the rhythmic alternations are especially typical of tidal environments, suggesting the river channels were tidally-influenced. The slack water periods would allow the deposition of thin muds, and the stronger flood or ebb currents would allow deposition of thin sandstones. The thicker alternation between rhythmites and dune-crossbedded sandstones is probably due to the meandering of the river bars and channels. A tidally-influenced riverine environment also explains the paucity of trace fossils within the base of the channels, because of the stress of extreme salinity and current fluctuations. It explains rare dinoflagellates and the occurrence of non-freshwater trace fossils towards the top of each channel-fill succession where conditions were more quiescent.

A better understanding of the depositional system at Glenelg has important implications for future exploration. For example, knowing that the river channels were tidally-influenced at the time of the maximum extent of the delta in this area implies proximity to the front of the delta system. If, by contrast, the channels were exclusively freshwater, it would imply that the delta front may lie much further out. The occurrence of tidally-influenced environments also has implications for the lateral continuity of the sandstones. It is common in such environments for the sandstones to be enclosed within less-permeable mudstone beds, and to have poorer connections to other sandstones than in ordinary river-deposited sandstones. The contrast between the depositional environments in the top and bottom parts of this interval also explains the distribution of the gas reservoirs. They are hosted in the fine-grained, well-sorted, wave-dominated shoreline sediments typical of the upper two, less-extensive phases of the delta system.

The Scotian Slope: The Unknown Frontier for Hydrocarbon Exploration

David J. W. Piper

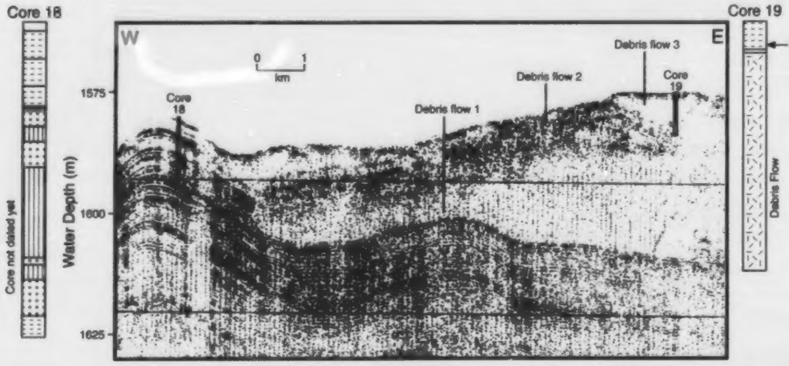
In the past two years, more than half of the area of the Scotian Slope has been leased for hydrocarbon exploration, with a large number of companies committing to invest at least $600 million in exploration. Lease blocks extend from the edge of the continental shelf to water depths of 3000 m.

The eastern part of the Scotian Slope is dissected by steep-sided canyons. Much of the western Scotian Slope is covered by debris flow deposits. Whether the seabed is sufficiently stable to support eventual production is an important question for companies investing in exploration blocks. The environmental issues associated with deepwater hydrocarbon exploration and development are the subject of public debate. What regulatory framework is appropriate for ensuring that exploration drilling and eventual production are not hazardous is a question for the regulator, the Canada-Nova Scotia Offshore Petroleum Board. All of these questions require a scientific understanding of the seabed in deep water.

Geological work on the continental slope in the 1980s was triggered by the drilling of five wells on the Scotian Slope in water depths of 1000-1500 m, and was restricted to detailed case studies near those wells. Since that time, the Geological Survey of Canada has done little work in deep water, except in support of paleoclimate studies for global change issues. With the renewed industry interest in deep water, major field programs were completed in the summer of 1999 and 2000 on the Scotian Slope, in partnership with many major industry players.

The availability of the Global Positioning System (GPS) and multibeam bathymetry technology since the 1980s has revolutionized our ability to investigate seabed features. Many geological hazards at the seabed, be they steep slopes, landslides, debris flows or pockmarks where shallow gas may vent, have a morphological expression that can be mapped by multibeam bathymetry. The morphological data and information on acoustic backscatter can be used to map biological habitats. Global Positioning System permits a ship to return to these features to take cores, photographs or run seismic profiles across the features.

Working in deep water demands tools that are different from those used on the continental shelf. Instruments lowered to the bottom require long cables, which in turn mean large winches and large ships such as the *Hudson* to operate them. Instruments also require pressure cases rated to full ocean depth. Spatial resolution of surface-towed multibeam and seismic profiling equipment progressively decreases as water depth increases; this problem is best resolved by towing systems near the seabed. Drag on the towing cable means that such operations must be carried out at ship speeds of less than two knots, requiring skilled seamanship to maintain a predetermined course.



Huntec Deep-Tow System high-resolution seismic profiling showing three stacked debris flow deposits west of Logan Canyon. Core 18 was taken from adjacent undisturbed seafloor to estimate the age of the two older debris flows. Core 19 was used to estimate the age of the youngest debris flow.

Understanding seabed hazards and environmental issues in deep water requires a scientific knowledge of how seabed sediments have accumulated. The pattern of sedimentation is particularly complex off Nova Scotia because only twenty thousand years ago ice sheets extended across the continental shelf and meltwaters poured sediment out into deep water. In some areas, deep canyons were cut at this time; in other areas, the continental slope was built up. These differences have a profound influence on both seafloor stability and environmental conditions.

A major cruise on the *Hudson* in 1999 collected high-resolution seismic profiles, 12m-long piston cores, measurements of ***in-situ*** pore pressure, and tested a new deep-towed seismic receiver. The data from this cruise show a remarkable number of shallow faults that reach the seabed and appear to localise landslides, perhaps through release of gas. Nevertheless, near-surface debris flows all appear to be at least 10,000 years old and are probably related to very different conditions during the last Pleistocene ice age. Our understanding of the Scotian Slope was greatly advanced in the spring of 2000 by collaboration in a multibeam bathymetry program by C & C Technologies and a group of petroleum industry companies. This survey covered more than 28,000 square kilometres of seabed. Additional multibeam was collected on the upper Scotian Slope in partnership with fishing and petroleum companies. Two *Hudson* cruises used this seabed imagery in order to precisely position seismic reflection profiles and cores for a focussed program investigating seabed hazards and environmental conditions. However, much work remains to be done if we are to fully understand the variability in seafloor conditions on the Scotian Slope and the potential risk of landsliding.

Tectonic and Hydrocarbon Implications for Davis Strait from Newly Compiled Geophysical Data - Gordon Oakey, Ruth Jackson, (GSC Atlantic), and Richard Whittaker (GeoArctic International Services Ltd.)

Until the early 1990s the Greenland and Canadian sectors of the Davis Strait shared a similar history of exploration. Oil exploration began with the drilling of five wells in West Greenland between 1976 and 1977, and three wells on the Canadian side of the Davis Strait between 1979 and 1982. Despite the 2.3 trillion cubic feet of natural gas tested at Hekja well in the Canadian sector (about half the estimated volume of gas reserves on the Scotian Shelf when the decision to develop a pipe line was taken) further exploration was abandoned due to the assessment that the area was gas-rather than oil-prone, and that any fields were likely to be too small to be economic.

Following a period of 20 years with virtually no activity, the oil industry's perception of the Davis Strait area was changed by two events that took place during 1992. Giant potential hydrocarbon traps with direct hydrocarbon indicators were identified on new seismic data in the Fylla area of West Greenland. In addition, significant oil seeps were found in the onshore extension of the basin. These events triggered the acquisition of more than 25,000 km of new industry seismic data off West Greenland and the granting of two new exploration concessions, shown by the red outlined areas below.

In order to have adequate base maps to further understand the complex interplate evolution between Canada and Greenland, a new initiative to compile geophysical data from 54°N to 84°N has been started to produce 1:1,500,000 scale maps of physiography (bathymetry and topography), magnetic anomaly, and gravity anomaly data. Four map areas will be covered by this compilation: Labrador Sea, Davis Strait, Baffin Bay, and the Innuitian Region. This project is a cooperative effort the Geological Survey of Canada Atlantic (GSCA), the Geological Survey of Denmark and Greenland (GEUS), Danish Kort and Matrikelstyrelsen (KMS), and the new territory of Nunavut. Data are from both historical archives and recent field activities.

The physiography grid is a merge of independently assembled topographic and bathymetric compilations with a final minimum resolution of 2 km x 2 km (Figure 1). Gravity data were gridded at 5 km resolution (Figure 2). Data sources include marine ship observations, aerogravity over Greenland, and station data over Baffin Island. Gravity data for land areas were adjusted for topography. Magnetic data were combined from various marine surveys, aeromagnetic surveys, and gridded sources with a grid resolution of 2 km (Figure 3).

The map set for the Davis Strait region is highlighted to address the scientific interests and economic potential of the area. Potential reservoir and source rocks are predicted at several levels throughout the sedimentary succession. Rifting and basin formation began in the Labrador Sea during the Early Cretaceous (~144 million years ago) and the earliest known sediments to be deposited in the initial rift basins are fluvio-deltaic and shallow marine clastics of the Bjarni Formation that are Cretaceous in age (~125-98 million years old). Reservoir rocks containing hydrocarbon discoveries on the Labrador Shelf are mostly of this age; however, the Hekja gas discovery was in a Paleocene (~65-55 million years old) sandstone reservoir. The giant gas prospects in the Fylla area are believed to be trapped in Upper Cretaceous (~98-65 million years ago) sandstone reservoirs. Gas source rocks responsible for the accumulations on the Labrador Shelf are also likely to have been deposited during the Cretaceous rift episode. Although the prolific Upper Jurassic (~163-144 million years ago) oil-prone source rock found on the North Atlantic margin is unlikely to be present in the Davis Strait area, the West Greenland oil seeps are from a latest Cretaceous to Paleocene deltaic source rock. Deltaic de-

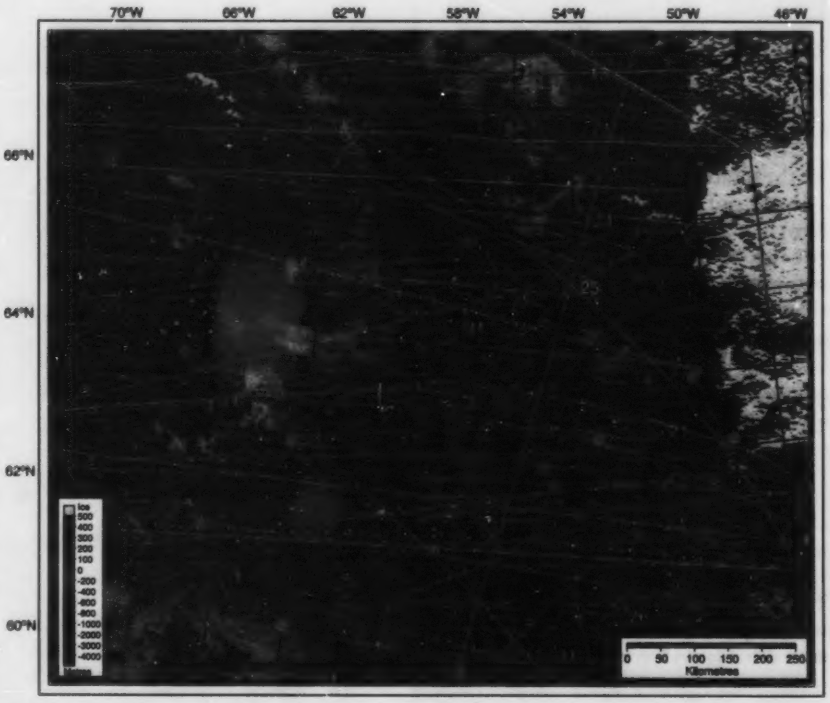


Figure 1. The physiography of the Davis Strait region. Shown are the positions of wells as◆ and the two new exploration concessions (red outlines). Also shown are the direction and amount of motion of the Greenland Plate relative to North America for identified magnetic reversal isochrons. The political boundary between Canada and Greenland is shown with a dashed line.

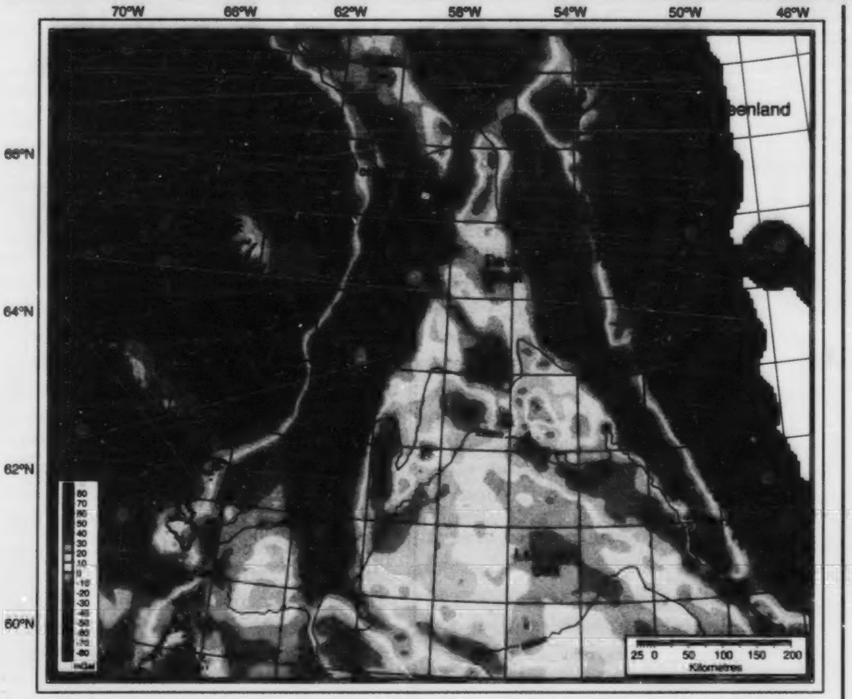


Figure 2. Gravity map of the Davis Strait region. The two parallel gravity anomalies from 66°-62°N are due to high density volcanic rocks at or near the seabed. The large anomaly to the south is related to a thick sedimentary wedge at the mouth of Hudson Strait.

posits of this age have been interpreted to be quite extensive throughout the Davis Strait - Baffin Bay area.

The timing and geometry of development and evolution of the basin systems within the Davis Strait region are closely linked to the plate tectonic history between Canada and Greenland. The linear patterns of magnetic anomalies over the deep oceanic basins provide paleo-plate boundaries used to reconstruct the continental plates. In Figure 1 the flow lines for two points on Greenland are shown with numbers indicating the magnetic anomalies identified as plate boundaries. Larger numbers are older in age. These flowlines show that there was a two-phase tectonic evolution with a sudden change in the direction of seafloor spreading at chron 25°N (56 million years) from northeast to north.

The GSCA and GEUS are currently integrating interpretations of data of the potential fields with seismic reflection data to identify the variability of basement morphology. The goal is to produce plate reconstructions that will help link the sedimentation history with the tectonic processes. For example, seaward of Cape Dyer and southward for 400 km, extensive volcanic rocks are mapped below the seabed. The hot volcanic intrusions change the thermal regime of the surrounding strata affecting hydrocarbon maturity. At the mouth of Hudson Strait a large positive gravity anomaly is coincident with a thick prograding sedimentary wedge. The combined potential field data and seismic reflection sections suggest that the continent-ocean boundary is nearer the coast than previous interpretations. This simplifies the plate reconstructions and makes it easier to determine the position of the Fylla structure adjacent to the Baffin and Labrador margins prior to seafloor spreading. Thus, the combined interpretation of the maps and the seismic profiles provide clues for hydrocarbon exploration on the Canadian margin.

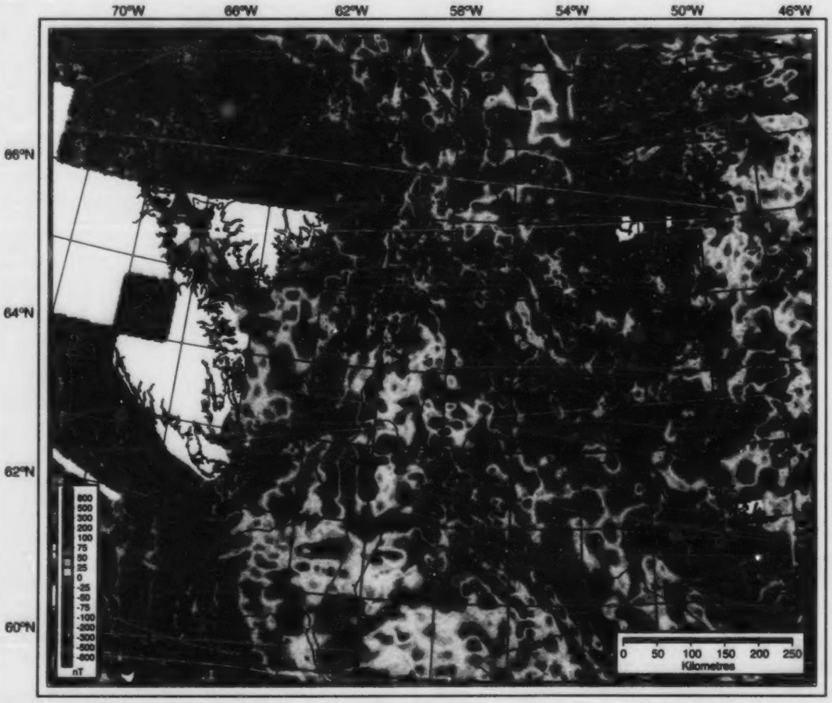


Figure 3. Magnetic map of the Davis Strait region. Magnetic anomalies are useful in defining the distribution of volcanic rocks. Onshore magnetic anomalies are generally higher amplitude and shorter wavelength than offshore due to the deeper sources.

Canadian Hydrographic Service

The Canadian Hydrographic Service Source Database

Steve Forbes, Robert Burke, and Herman Varma

During the past decade the Canadian Hydrographic Service (CHS) has implemented new digital bathymetric data collection systems. These systems provide the capability for 100% sea floor coverage. Systems such as the Simrad EM3000 Multibeam Swath Sounder have the potential to gather approximately 2800 million depth measurements during a three-month survey. This translates to 280 gigabytes of information. Five similar EM3000 surveys in one survey year can gather in excess of one terabyte of data. This volume of data requires new techniques for the aggregation and management of spatial information.

The Canadian Hydrographic Service is addressing this challenge by implementing a national Source Database (SDB) to manage the very large volume of bathymetric information and source information using a Relational Database Management System (RDBMS). The SDB is being implemented using Oracle 8.

The management of temporal/spatial data has been under investigation by the CHS since the 1980s. A key and innovative breakthrough came with the development of a spatial data type called Helical Hyperspatial Code (HHCode) during 1989. This new method of data encoding facilitated the efficient storage and manipulation of spatial data in a RDBMS environment.

Oracle Canada and the CHS entered into a collaborative agreement to transfer some of this technology to Oracle's Database Applications. Oracle has incorporated additional temporal/spatial capabilities based on this technology and now offers it as an option called Spatial Data Option (SDO).

During the five-year term of the collaborative agreement with Oracle, which terminates in February of 2001, the CHS has realized significant benefits in terms of software licenses, product support, and training.

The Helical Hyperspatial Code (HHCode), in conjunction with the evolution of powerful and affordable computer systems, has made it possible to deliver the Source Database application.

The primary objective of the SDB is the management of the source information to enhance the production and maintenance of CHS products and to make the data accessible to clients. The products are developed using bathymetric and ancillary information collected by the CHS and other mapping agencies, and include the nautical chart and the Electronic Navigation Chart (ENC). There is no commercial product at this time using an Relational Database Management System that addresses the objectives as stated. The CHS, Holonics Data Management, CubeWerx Inc., and Helical Systems designed and developed the applications that are needed to meet these requirements.

To address a project of this magnitude, it was necessary to develop the application in three phases. Phase I, the management of the very large volume of bathymetric information, was considered the most challenging. This portion of the SDB was implemented in the CHS national offices during the period November 2000 to March 2001.

Phases II and III address the additional point and line features necessary for producing CHS products. The primary components for these two phases have been developed and will be integrated with the bathymetric data management system. Addressing these phases is planned using Rapid Application Development (RAD) and this will accelerate their delivery. Implementation of Phase II and Phase III is planned for 2001.

To realize its full potential, the Source Database will need to be populated with current and historical source information. To address this issue it is anticipated that the legacy source information will be verified and loaded into the database based on production priorities. This will guarantee that only the legacy information required for the delivery of products and services will be conditioned and loaded in the database. All new verified digital information, for example from modern hydrographic surveys, will be loaded in the database.

In addition, the SDB application will be integrated with existing data collection, data manipulation, and production processes. This will facilitate the smooth flow of information from data acquisition to production. To provide operational flexibility, the basic design allows for different data sets with different datums (both horizontal and vertical) to be stored and manipulated within the database.

As the product database and the source database mature, it is expected that their distinction as independent linked applications can be transformed into a seamless digital data management system that can produce products and services.

The Canadian Hydrographic Service also needs to access data that are owned and managed by other agencies. The SDB has been designed to provide access to external databases needed to provide this additional information. CHS only stores and manages data that are under its custodianship and does not duplicate and manage external agency data.

To meet its mandate, the CHS must manage its vast store of source information in a manner that ensures accessibility, data integrity, security, and efficiency. The Source Database application will provide the tools and data management environment to deliver this objective.

Nautical Charting - Richard MacDougall

The responsibility for the nautical charting of Atlantic Canada's waters lies with the Canadian Hydrographic Service (CHS) at the Bedford Institute of Oceanography. The present suite of 287 paper charts date from the days of Captain Cook to the present with 49 Newfoundland charts being direct copies of 18th and 19th century British charts. Many newer charts are the result of hasty, partial surveys during World War II. Only a third of the region's paper charts can be used directly with the Global Positioning System (GPS) due to difference in horizontal datum.

The reduction of budgets, personnel and vessels in recent years has resulted in the use of risk management and a more focused approach to meeting increased demand for accurate and up-to-date charts. Modern surveys no longer systematically survey an area from shore-to-shore but concentrate on surveying ports, channels into the ports and corridors between ports. In these areas, multibeam sounding systems are used to acoustically sweep 100% of the bottom for hazards to navigation. These surveyed areas are clearly depicted on charts to alert users to the fact that areas outside the corridors are not completely surveyed.

Technology advances in geographic information systems (GIS) and printing also support this triage approach to charting highest risk areas first. Data are collected digitally and transformed into a nautical chart using digital compilation techniques. When this is combined with Print-On-Demand (POD) technology a chart can be produced and printed quickly and economically. The advantage is that when additional data are collected they can be easily processed, added to the chart file, and the next POD prints will show the new data. This POD approach is being used for applying changes advertised in Notices to Mariners as well as incorporating new survey data.

In parallel with the reductions in CHS, the demand for new products increased. Mariners have equipped vessels with the Global Positioning System (GPS) and with non-standard electronic chart systems (ECS) and more recently, with type-approved Electronic Chart Display Information Systems (ECDIS) that meet international performance standards for equivalency to the use of paper charts. To meet this demand, the CHS released raster electronic charts and vector Electronic Navigational Charts (ENC).

The raster electronic charts are digital images of the paper charts, with notes, insets, titles, compass roses, borders, and grid lines visible. The data are portrayed as coloured pixels on the computer screen and do not contain additional attributes that describe the identifiable features. The electronic chart systems integrate the Global Positioning System position of a vessel with the electronic chart data and automatically plot the vessel position. This has the advantage of showing the vessel where it is in real time and not where it was a few minutes ago which is the case when a mariner uses traditional navigation techniques to sight targets, then manually plots the information on a paper chart. All raster electronic charts have been referenced to the same horizontal datum as the Global Positioning System. At present, the region has 200 of the 287 paper charts in raster format.

The vector Electronic Navigational Charts provide the same positioning functionality as the raster electronic charts but have the additional benefit of allowing users to customize their view. This means a user can turn on or off certain features to get more detailed information or reduce clutter and program alarms to sound when dangers or administrative boundaries such as international boundaries, harbour limits, and vessel traffic call-in points are approached. Electronic Navigational Charts must be in the internationally agreed S-57 data format and conform to the S-52 data content standard. S-57 is the International Hydrographic Organization (IHO) standard for the coding and exchange of digital hydrographic data. S-52 is the IHO standard for data content on Electronic Navigational Charts. To be certified as an Electronic Chart Display and Information System (ECDIS), an electronic chart system must meet international performance standards set by the International Maritime Organization (IMO) and must use an official Electronic Navigational Chart. At present, 80 of the region's 287 paper charts have been converted to Electronic Navigational Charts.

CHS has been a world leader in developing the S-57 and S-52 standards. Much of the Canadian input came from involvement in an electronic chart demonstration pilot which utilized government and commercial vessels in electronic chart system trials. One of the early adopters of the electronic chart technology was Canada Steamship Lines which outfitted 11 vessels and asked CHS for 166 electronic charts – none of which existed. This prompted CHS to focus on electronic charting and the shipping industry to prioritize both the charts they required in electronic form and the content of the charts. As the pilot project progressed, more features were added to the electronic charts and this first-hand experience contributed to the development of the international standards.

In the early stages of electronic chart system (ECS) development, two Canadian companies played a prominent role, Matrix Technologies of St. John's with a raster ECS and Offshore Systems Limited of Vancouver with a vector system. Both were demanding electronic chart data and permission to make their own versions for CHS paper charts. The CHS-preferred approach was to have one official data set and not multiple versions. However, CHS lacked the resources to realize this objective and had no infrastructure to support the sale, licensing or distribution of digital data. To address the issue, Matrix and Offshore Systems Limited formed Nautical Data International Inc. (NDI). NDI was successful in reaching an agreement with CHS for the sole right to distribute digital CHS products.

In addition to CHS using Nautical Data International Inc. as a private sector distribution arm, CHS contracted to a number of companies for the conversion of paper charts into electronic chart form, thus developing Canadian private sector expertise in electronic charting. CHS has been careful to strike a balance between contracting and doing sufficient work in-house to maintain the expertise needed to prepare specifications for work and do quality assurance.

CHS has also played a major role in the development of Canadian expertise in digital charting and data base tools for managing large volume hydrographic data. The CARIS system now in use in over 30 countries for the production of paper and electronic charts grew out of CHS in-house technology that was transferred to Universal Systems Ltd. of Fredericton.

While the electronic charts are easier to change and update than paper, the demand for paper charts remains strong. To improve shipping, fishing efficiency, and safety, the electronic chart users demand super scale docking charts, real time water levels, accurate depth information, and seabed imagery. Balancing new possibilities with traditional demands is the challenge CHS faces as we move into the 21st century.

Ocean Sciences

Improving the Skill of the Canadian Search-and-Rescue Planning System (CANSARP) - Peter C. Smith, Don Lawrence (Ocean Sciences), Josko Bobanovic, and Keith R. Thompson (Dalhousie University)

The Canadian Coast Guard (CCG) is responsible for marine search-and-rescue (SAR) in Canada's offshore waters. Their primary planning tool is the CANSARP system, an ocean model that uses meteorological forecasts and diverse ocean observations to define the appropriate search area. Under CCG sponsorship, a research project has been undertaken to improve the accuracy and forecast skill of CANSARP through the air deployment of satellite-tracked drifters (self-locating datum marker buoys or SLDMBs) and the use of a data-assimilating coastal ocean prediction system, based on a sophisticated circulation model developed at Dalhousie University in Halifax, NS.

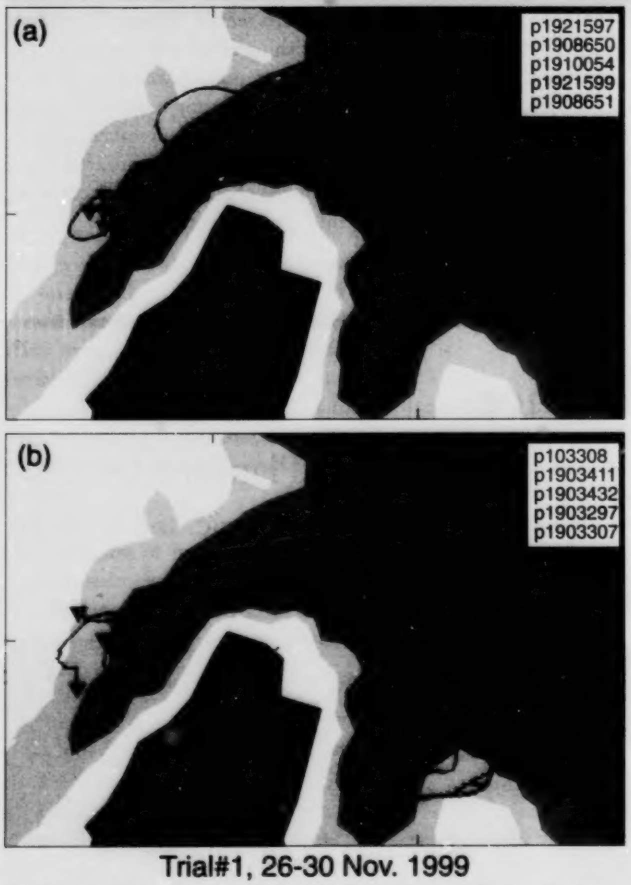
In an actual search-and-rescue incident, a cluster of satellite-tracked marker buoys would be dropped near the last known position of the search targets and subsequently tracked to provide near-real-time estimates of the local surface drift field. The Dalhousie forecast system would provide immediate predictions of the target drift for planning of the initial search area. Later, it would incorporate the marker buoy data to provide refined drift predictions, thereby narrowing the search.

The Dalhousie model is driven by forecast winds produced by Environment Canada. It also features the seasonal mean density-driven component in order to simulate the proper structure of the current field. In the all-important surface layer, special care is taken to create a realistic current profile. Because search-and-rescue targets are generally floating objects protruding from the surface, an additional "leeway factor" must be added to account for the wind acting on the exposed surfaces pushing the object through the water. These factors will be different for different objects, such as a person-in-water or a life raft.

An improved version of the Dalhousie model was tested during a number of field trials conducted in the southern Gulf of St. Lawrence and Cabot Strait during Nov.-Dec., 1999. These trials were similar to those conducted on the Scotian Shelf during February, 1996 (Smith, et al., 1998), except the marker buoys were not used at that time and the model forecasts (CANSARP and Dalhousie) were carried out "after the fact". The earlier tests showed a measurable improvement in the skill of the Dalhousie model over that of the standard CANSARP forecast.

(a) Liferaft, Accurate Surface Tracker (AST) and two low-cost drifters (LCDs); (b) AST and LCD adrift at B1, trial #1.

During the 1999 trials, clusters of target buoys were deployed in a "cross" pattern centred on the "last known position" of the hypothetical search-and-rescue incident. The crosses varied from 1 to 2 nautical miles in length. The primary drifter, SEIMAC's Accurate Surface Tracker® (AST), is a flooded barrel-shaped buoy, whose leeway characteristics closely match those of a person-in-water. The low cost drifters (LCDs),



(a) Accurate Surface Tracker® (AST) and (b) Self-Locating Datum Marker Buoy (SLDMB), configured as a person-in-water (PIW), drift tracks for trial #1, 26-30 November, 1999.

originally manufactured by Draper Laboratories in Massachusetts, USA, were designed with a very shallow draft to simulate the behaviour of the leading edge of an oil slick, or very light (buoyant) debris on the surface. The 4-person life rafts were ballasted with roughly 100 kg and deployed with or without a sea anchor. Because of their higher ratio of exposed to submerged area, the leeway factors for both the low-cost drifters and the life rafts are considerably higher than those of the Accurate Surface Trackers (amounting to 3-4% of the local wind speed).

Under the influence of strong winds and currents, the behaviour of the clusters of different buoy types during the three trials was qualitatively similar, but quantitatively different. The self-locating datum marker buoys can be configured to simulate either a person-in-water (PIW; low leeway) or a life raft (LR; high leeway). During trial#1, the trajectories of the Accurate Surface Tracker buoys show similar patterns to the datum marker buoys configured as person-in-water despite being launched 5 hours later.

The life rafts and the low cost drifter buoys were more responsive to the wind during this (and later) trials. Adverse easterly winds during this trial retarded of the movement of these objects around Cape North and into Cabot Strait. Very strong easterly winds also dominated the drift in trial#2, resulting in the beaching of all but two drifters shortly after their release in Cabot Strait. Moderate winds returned in trial #3 and currents again dominated the drift patterns.

Initial runs of the Dalhousie model and CANSARP indicate that important discrepancies between the forecast and observed drift trajectories appear to be related, at least in part, to poor forecasting of the marine winds. Present efforts are directed at producing optimal wind fields for the trials, after which a careful attribution of the remaining error sources will be made, retrospectively, for both forecast systems. Additional ancillary measurements of the current and ocean density fields obtained during these trials will contribute to these analyses.

The development of sophisticated, real-time surface current models, formulated and tested through collaboration and partnership between Dalhousie University and BIO scientists, promises to provide improved skill in surface drift forecasts for search-and-rescue planning, as well as a number of other emergency response issues (such as oil spill response).

References

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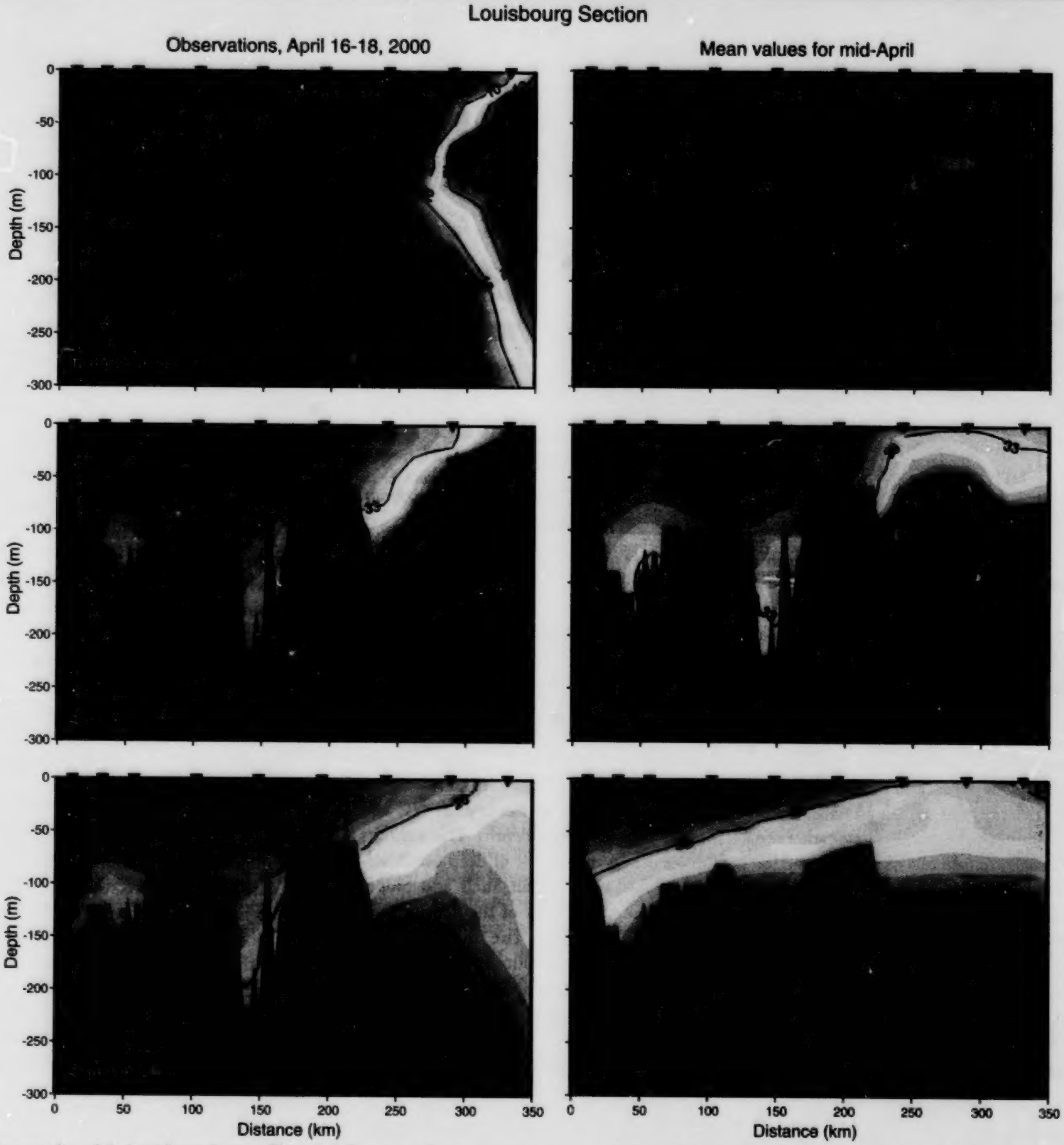
Atlantic Zonal Monitoring Program - Michel Mitchell

The waters of Eastern Canada are the arena of a multitude of activities—commercial and recreational. Many of these activities are highly dependent upon the state of the oceanic ecosystem and environment, which are very complex and are subject to natural variations occurring over a wide range of periods. The sound development of ocean activities demands a greater understanding and description of this complex environment and its marine ecosystem.

To address these needs, DFO scientists initiated the Atlantic Zonal Monitoring Program (AZMP). The AZMP is an ongoing program of collection and analysis of biological, chemical and physical data to characterize and understand the causes of oceanic variability at seasonal, interannual and decadal time scales. Over the longer term, this multidisciplinary dataset will be used to establish relationships among the biological, chemical, and physical variables.



Louisbourg Section

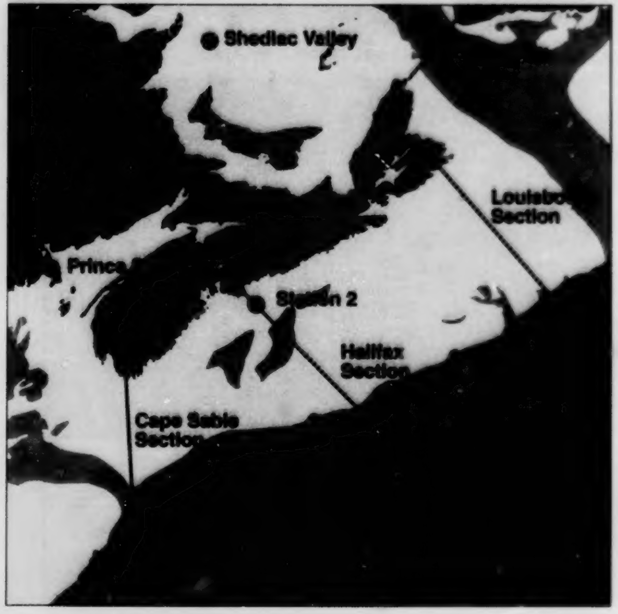
Observations, April 16-18, 2000

Mean values for mid-April

Contour plots of the Louisbourg Section. The panels from top to bottom are temperature, salinity and density. The left-hand panels show data for April 2000. The right- hand panels show the mean values for the month of April as calculated by optimal estimation. The ocean bottom is in black.

Scientists at BIO are responsible for the development and implementation of a cost-effective program covering the Southern Gulf of St. Lawrence, Scotian Shelf, Gulf of Maine and Bay of Fundy. Fixed sites are sampled every two weeks from small boats, and sections across the continental shelf are sampled one to three times per year from major oceanographic research ships. The principal measurements include temperature, salinity, light penetration, zooplankton and phytoplankton samples, nutrients and oxygen concentration. This conventional field sampling is complemented by remote sensing of ocean colour and temperature from satellites. Data from cruises of opportunity as well as from the Continuous Plankton Recorder survey (CPR, from the Sir Alister Hardy Foundation for Ocean Science) also supplement the dataset.

The data collected, as well as various data products, are available to the public via the AZMP website at http://www.meds-sdmm.dfo-mpo.gc.ca/zmp/main_zmp.html and as a database at http://www.mar.dfo-mpo.gc.ca/science/ocean/database/

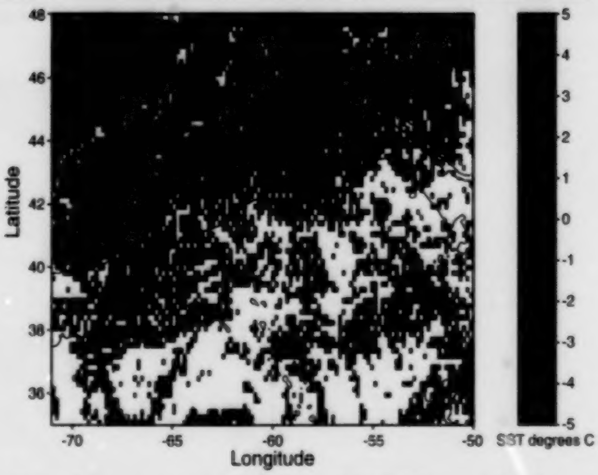


Location of the sampling sites. The sections are sampled up to three times per year. Fixed sites, as indicated by large red dots are sampled bi-weekly.

data_query.html. Satellite imagery is available at http://www.mar.dfo-mpo.gc.ca/science/ocean/ias/seawifs/seawifs_1.html.

The program formally began in 1998 although measurements at some sites such as Prince 5, Station 2, and the Halifax Section have been carried out on an irregular basis for a number of decades. These earlier measurements were largely of physical variables; the systematic observations of biological and chemical variables are the important new focus of the program.

An April sampling of all sections characterizes the state of the system near the time of the spring productivity peak. During the 1990s, the water of the Eastern Scotian Shelf has been colder than normal. The April 2000 Louisbourg Section survey reveals the entire water column of the Shelf is warmer than the mean by 1 to 2°C. More striking however, is the deep slope region where the temperature increase is as large as 4°C and reaches much greater depths. This suggests a significant movement of deep ocean water toward the Scotian Shelf and Slope. Comparing the slopes of the density lines for April 2000 to the mean of the Louisbourg Section contour plots (sigma-t of the figure) suggests an increased eastward flow of Warm Slope Water in April 2000 compared to the long-term mean. The sea surface temperature data from satellite imagery show that the entire Shelf has warmed, most likely the result of atmospheric exchange, but it also reveals a maximum warming in a narrow band trapped at the Shelf edge as was detected at the outer Louisbourg Section. When the complete dataset, including the biological and chemical data, has been analyzed, it may be possible to identify links between these changes in flow patterns and the state of the ecosystem.

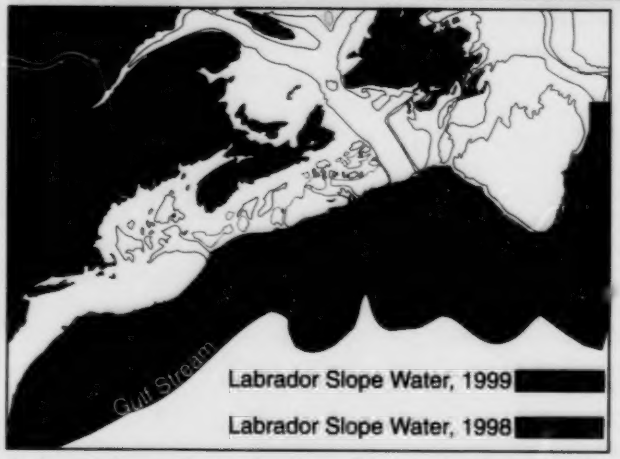


Sea surface temperature anomaly for April 2000. The anomaly is the difference between the April 2000 values and the long-term mean of archived data for the month of April.

A current focus of our research is to develop simple indices to use as accurate indicators of the state of important ecosystem components. As the AZMP evolves and the database of amassed information grows, we will be better able to identify the important variations and have a better understanding of their potential consequences.

Monitoring Reveals Significant Changes in the Ocean Climate on the Scotian Shelf and in the Gulf of Maine - Ken Drinkwater and Charles Tang

Fisheries and Oceans' increased monitoring of eastern Canadian waters in recent years has provided a good description of the advance and retreat of unusual ocean conditions between 1997 and 1999. In early 1997, current meter moorings detected a sharp drop in temperature and salinity off the southern slope of St. Pierre Bank to depths deeper than 500 m. By the early fall of 1997, colder-than-usual water appeared offshore of Banquereau Bank at depths of 100-400 m. During the fall and winter of 1997/98 this water moved southwestward along the continental slope at an average rate of between 5-10 km per day. By April 1998, it lay along the continental slope adjacent to the shelf all the way from Banquereau Bank to the Middle Atlantic Bight off New York City. Known as Labrador Slope Water, it has temperatures of 4°-8°C and salinities of less than 34.8. As it moved southwestward, it forced Warm Slope Water, which had occupied this region for most of the last 30 years, farther offshore. Warm Slope Water has tem-



A schematic diagram showing the position of the Labrador Slope Water and Warm Slope Water at approximately 200 meters in 1998 and 1999.

peratures of 8°-12°C and salinities greater than 34.8. As the Labrador Slope Water extended southward, temperatures in the affected areas dropped by 4°-6°C and salinities by 0.5 to 1.

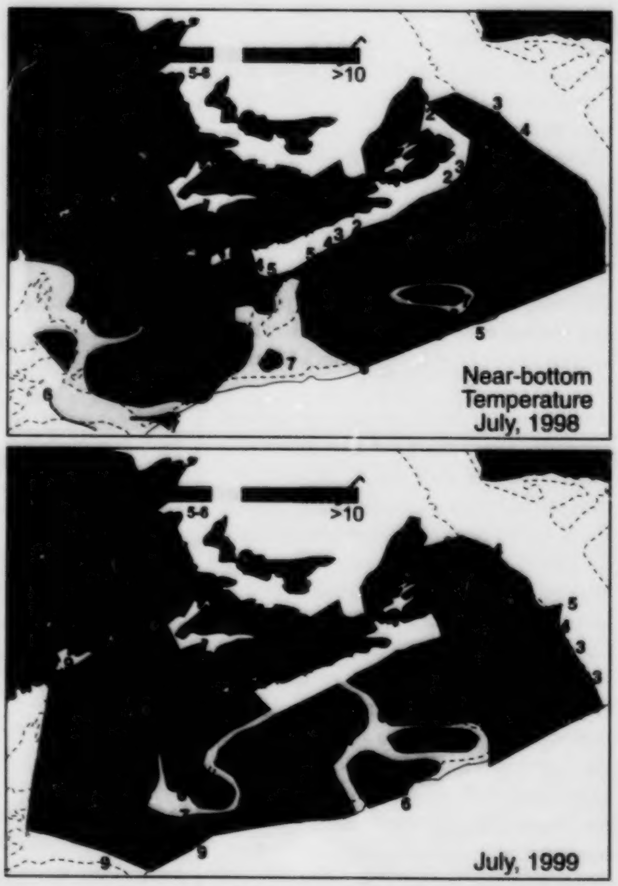
The cold Labrador Water was not confined to the continental slope region. After reaching offshore of Emerald Bank southeast of Halifax in October 1997, it began to flow onto the shelf through the Scotian Gulf between LaHave and Emerald banks. In December it was at the offshore edge of Emerald Basin on the central Scotian Shelf and by mid-February it had replaced all of the water in the Basin deeper than 100 m. Between mid-December and mid-February temperatures in the Basin dropped by 4°C and salinities by 1. Over the early months of 1998, this cold water replaced the near-bottom waters over the entire southwestern Scotian Shelf leading to the coldest waters in this region (3° to 7°C) since the 1960s. The cold Labrador Slope Water also entered the Gulf of Maine. It was first observed at the entrance to the Northeast Channel in January 1998. By April, it had completely replaced the Warm Slope Water that had occupied Georges Basin and Crowell Basin. It was not until the summer, however, that the effects of the Labrador Slope Water were observed in the inner Gulf of Maine in the deep basins such as Jordan and Wilkinson. In contrast to Georges and Emerald basins where the Labrador Slope Water completely replaced the Warm Slope Water, in the inner Gulf of Maine the Labrador Slope Water appeared to mix equally with the resident waters.

Through 1998, the Labrador Slope Water gradually retracted northeastward along the slope so that by the beginning of 1999 it had retreated to its usual location near the entrance to the Laurentian Channel. Warm Slope Water again occupied the continental slope region from the Middle Atlantic Bight to the Scotian Shelf. As the Labrador Slope Water was replaced, the temperature and salinity of the deep shelf waters slowly began to rise. By the beginning of 1999, much of the Labrador Shelf Water in Emerald Basin had been displaced. In July 1999, the annual DFO groundfish survey showed that the entire southwestern Scotian Shelf had returned to conditions similar to those observed prior to the invasion of the cold Labrador Slope Waters, i.e. temperatures of 5° to >9°C.

The arrival of the cold water on the shelf had significant effects on the catchability of some fish species, as reported by fishers. For example, in Emerald Basin, a rapid decline in the commercial catches of shark was noted in the late winter and early spring of 1998. Sharks usually prefer waters warmer than 8°C, so apparently left when the cold Labrador Slope Water replaced the Warm Slope Water in the Basin. On Georges Bank and over its slopes, American fishers saw a decline in the catch rate of lobster. They attributed this to the presence of the colder water. Lobsters are known to be less active in colder temperatures, resulting in less chance that they will encounter a trap.

Southwestward incursions of Labrador Slope Water have occurred previously but in recent times they have been relatively rare. The last notable incursion was in the late 1950s and 1960s, when these waters remained off the Scotian Shelf and the Gulf of Maine for approximately a decade. As in the recent event, this cold water flowed onto the shelves. As a result, the coldest period in the last sixty years was recorded during the 1960s. A similar event also is believed to have occurred in the early 1880s and contributed to a large tilefish kill along the continental slope of the Middle Atlantic Bight.

What causes such events? Earlier studies suggest that the southward extension of the



The bottom temperatures in July 1998 and 1999 taken during the annual groundfish survey.

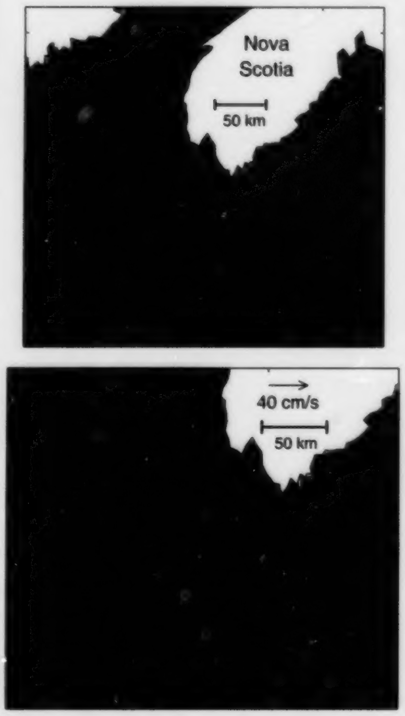
Labrador Slope Water occurs in those years when the density-driven (known as the geostrophic) component of the volume transport of the Labrador Current increases. This in turn has been shown to be related to the large-scale atmospheric circulation patterns, in particular the North Atlantic Oscillation (NAO) Index. This index is defined as the winter time sea level pressure difference between the Azores and Iceland and as such is related to the strength of the westerly winds across the mid-latitudes of the North Atlantic. An analysis of satellite altimeter data and hydrographic data taken in the Labrador Sea from 1993 to 1999 shows that in years when the index is low, the geostrophic transport of the Labrador Sea gyre increases. These transport variations appear to be associated with changes of temperature/salinity structure over the lower continental slope.

The relation between the winter NAO index and transport suggests that the water properties in the western Labrador Sea may be related to large-scale atmospheric forcing through air-sea interactions and water mass transformation. We believe that the large decline in the NAO index in the winter of 1996 led to an increase of the transport of the Labrador Current east of the Grand Banks approximately one year later, and eventually to the extension of the Labrador Slope Water southward to the Middle Atlantic Bight. Subsequently, the NAO index rose. This is thought to have led to a decrease in the geostrophic transport of the Labrador Current and eventually the retraction of the Labrador Slope Water northward to the Laurentian Channel by 1999.

Towards Predictive Modelling of Larval Survival and Recruitment of Browns Bank Haddock - David Brickman, Charles G. Hannah, Nancy L. Shackell, Kenneth T. Frank and John W. Loder

Browns Bank is the principal spawning ground for haddock off southwestern Nova Scotia. Historically, the haddock fishery in this area has supported average annual landings of about 18,000 t. Since the late 1980s the catch has been less than half of this, reflecting a reduction in the spawning stock biomass due to increased fishing pressure. At the same time, recruitment — the number of young fish reaching a fishable or mature age — approached historic lows. Recently, due to decreased fishing pressure and increased recruitment, there has been an indication of a rebound in stock biomass.

The mean circulation in the region shows generally southwestward flow along the western Scotian Shelf that turns north into the Gulf of Maine in the vicinity of Browns Bank. Embedded in this flow is a small partial gyre over the Bank's cap. This circulation has been shown to influence the distribution of haddock eggs and larvae. Campana et al. (1989) observed that the majority of larval haddock appeared to be retained on or near Browns Bank, but a portion of the population was advected towards the Bay of Fundy. They proposed that variability in the leakiness of the gyre influenced the proportion of larvae retained and, subsequently, recruitment variability.

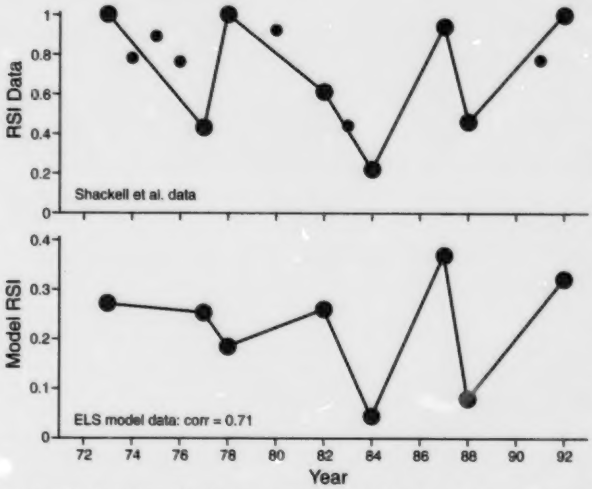


Top: Location map of the study area off western Nova Scotia. Bottom: Model predictions of the climatological spring currents in the upper 5 m.

As part of the GLOBEC (Global Ocean Ecosystem Dynamics) Canada program, a study of environmental influences on haddock variability has been carried out. Since there are no long time series of egg and larval distributions, Shackell et al. (1999) used the length at age-2 (yrs) to estimate the proportion of each year class retained in the Browns Bank region. This Retention-Survival Index (or RSI) takes advantage of the observation that juvenile haddock collected in the Bay of Fundy are, on average, larger than those collected around Browns Bank. In some years, there are two peaks in the length distribution of haddock, which is interpreted as representing a mixture of those retained on Browns Bank who grew slowly during early life, and others which were advected to the Bay of Fundy and grew more rapidly. Here we report on the use of an early life stage (or egg and larvae) model to investigate whether the variability in the age-2 RSI is the result of dispersal and survival processes occurring during early life stages, and discuss extension of the model to recruitment prediction.

The early life stage model includes: (1) a realistic egg production component describing the space/time distribution of spawned eggs; (2) a growth and survival component with constant (exponential) egg mortality, larval growth depending on age and temperature, and size-based larval mortality; and (3) a drift and dispersal component that computes the trajectories of egg and larval masses in realistic three-dimensional flow fields from a numerical circulation model. The latter includes the climatological seasonal-mean circulation and strong semidiurnal tidal currents and monthly circulation changes due to variable wind stress and upstream inflow.

The model was used to predict the age-2 RSI for a subset of years that represent the major trends in the time series. The model and observed indices are similar, indicating that the age-2 RSI is a reflection of processes occurring during early life stages.



Top: RSI data from Shackell et al (1999). The blue dots are years not simulated by the early life stage model. Bottom: RSI values from the early life stage model.

One of the outputs of the early life stage model is the number of survivors at the end of the larval stage. This provides the potential for coupling the model to one describing survival during the juvenile phase to produce a recruitment prediction model. However, the model described above did not include year-to-year temperature variability, nor variability in initial larval length due to the size structure of the spawning population, both of which are potentially important factors to larval survival.

The early life stage model was modified to include these two effects. Below is the age-1 recruitment time series for 4X haddock, and the number of surviving larvae as estimated from the original early life stage model (model-0) and the new model. The similarity between model-predicted surviving larvae and age-1 recruitment is significantly higher using the new model.

The estimated recruitment using the new model coupled to a simple constant mortality juvenile phase model is shown below. The mean error is less than 8% — for 6 out of the 8 years considered — indicating the potential for a process-based model to predict recruitment for haddock in this area and possibly other marine fish populations.

The source of recruitment variability in marine fish populations has been the subject of intensive study for nearly a century, with limited success. The GLOBEC investigations of Browns Bank haddock are indicating that linked early life stage and hydrodynamics models which incorporate key biological and physical processes, and their spatial and temporal variability, provide the potential for a significant advance in understanding and predicting recruitment variability.

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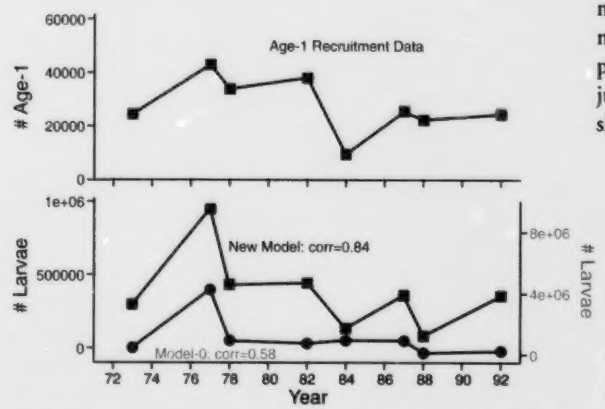
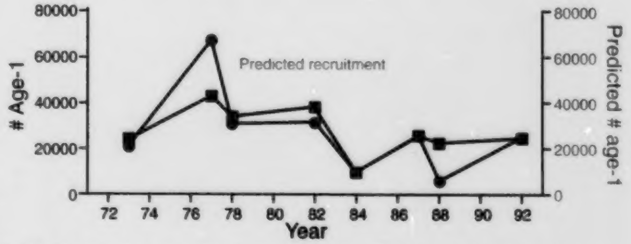


Top: 4X age-1 recruitment data from Sequential Population Analysis. Bottom: Number of surviving larvae from original early life stage model (model-0) and new version.



Prediction of age-1 recruitment using the new model coupled to a simple juvenile phase model.

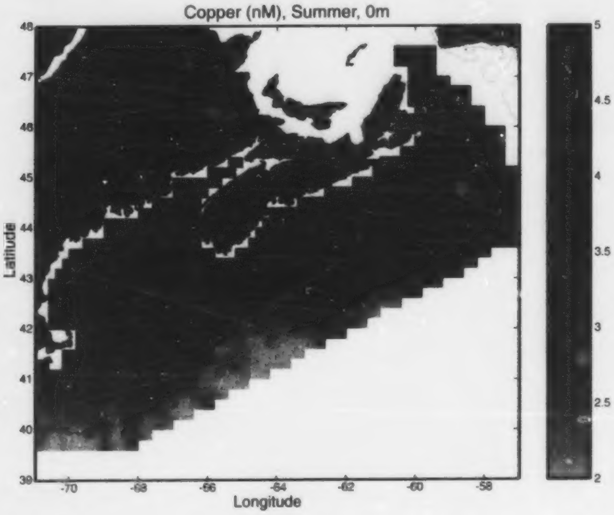
Marine Environmental Sciences

Fate and Effects of Marine Contaminants

Phil Yeats, Peter Cranford, and Simon Courtenay

There has been a general decline in marine environmental quality during the last few decades, particularly in the coastal zone where there are high inputs of industrial, agricultural and domestic wastes. Determination of the potential environmental hazard posed by various contaminants requires knowledge of: (1) chemical composition and concentration in the marine environment; (2) transport rate, pathway and ultimate fate; (3) toxicity to exposed organisms; and (4) bioaccumulation potential. Scientists in the Marine Environmental Sciences Division (MESD) are working to address gaps in science and technology to help understand these important physical, chemical, and biogeochemical processes. Research programs are currently focusing on Sydney and Halifax harbours, the two most heavily industrialized harbours in Nova Scotia, near pulp and paper mills, and around offshore oil and gas drilling platforms. The knowledge obtained from these studies on contaminant exposure and biological effects forms the basis for the development of policies and regulatory regimes for environmental protection and conservation.

Marine organisms are directly exposed to dissolved and particulate contaminants in the water column and/or sediments and are indirectly exposed through their food sources. Contaminant levels in the water column are subject to extensive spatial and temporal variability caused by fluctuations in contaminant inputs and water circulation. Studies of the biogeochemical processes governing these fluctuations are underway to improve our understanding of the processes controlling the distributions of contaminants between dissolved and particulate phases, between the water column and sediments, and the relationships between contaminants and environmental conditions. These studies help us to predict marine contaminant distributions such as the one shown below.



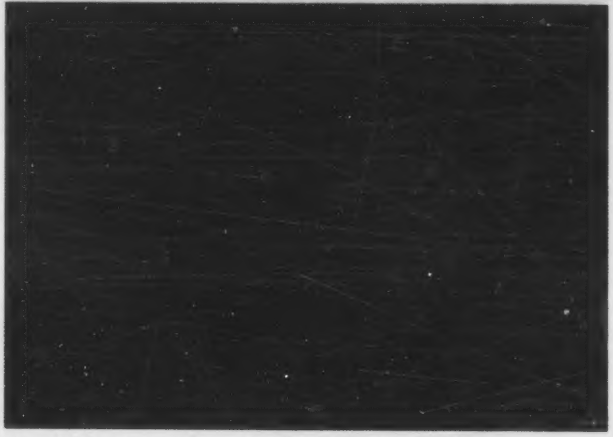
Optimally estimated copper distribution for the Scotian Shelf.

Radionuclide and other contaminant tracer measurements provide valuable insights into the transport pathways and fate of different contaminants and the rates of environmental reactions. For example, studies of contaminant concentrations in radioactively dated sediment cores provide a time history of contaminant inputs to the sediment. This ability to describe and forecast contaminant levels (exposure) greatly increases our capacity to predict their impacts on marine organisms, populations and communities.

Studies of contaminants in biota (dose), and their biological effects (response) are important components of our program. Elevated levels of contaminants in biota are not necessarily directly associated with biological effects, but for exploited species they can cause a human health concern and result in fishery closures if contaminant levels exceed established guidelines. Work on contaminant dose has focused on lobsters and mussels, important resource species in Atlantic Canada. Lobster habitat includes many industrial areas and surveys of contaminant concentrations in lobster digestive glands have documented specific industrial contamination of the fishery in Belledune and Sydney harbours. Another interesting observation is the large variability in copper concentrations seen in a broad survey of metal concentrations in lobsters caught throughout the Maritimes. This survey shows very high concentrations of digestive gland copper in lobsters caught in the upper reaches of the Bay of Fundy. The linkage between levels of copper in this environment (exposure) and levels in the lobster (dose) is currently being investigated.

Exposure to contaminants can result in numerous biological effects including evidence of stress, reduced growth and reproductive output, physical abnormalities, disruption of hormone and endocrine systems, and mortality. One remarkable example is the occurrence of imposex (sex reversal) in whelks in many harbours in the Atlantic Region as a result of exposure to low levels of tributyltin. Controlled laboratory studies are being conducted at BIO to establish relationships between contaminant dose and biological effects for different organisms and contaminants so that biological effects in natural populations may be better understood and anticipated before effects become severe. The sensitivity of techniques for measuring biological effects has greatly improved over the last decade and new technologies are being developed at BIO to detect temporal and spatial fluctuations in marine pollution effects. An example is the development and testing at pulp and paper and offshore oil and gas sites of a new automated biological effects monitoring system called HABITRAP. The HABITRAP provides a continuous record of the feeding rate of bivalves (scallops, mussels, etc.), a response that is highly sensitive to the presence of contaminants and relevant to population health and the fishery as it is closely related to reproductive output and growth.

HABITRAP being recovered at Hibernia.



Spinal deformity in a Miramichi River juvenile mummichog.

Fate and effects research being carried out by MESD scientists contributes to a national focus on Marine Environmental Quality (MEQ). The ability to quantify MEQ is critical for implementation of Canada's Oceans Act. The success of Marine Protected Areas in protecting unique or sensitive resources and the success of Integrated Management plans in ensuring the sustainability of particular activities both depend on being able to assess and monitor the quality of the environment. To this end, MESD scientists are testing the utility of different frameworks and indicators for measuring environmental health. New potential biomarkers being investigated include developmental problems in the early life stages of fish and and immune function in both fish and bivalve molluscs.

In New Brunswick's industrialized Miramichi River estuary and Nova Scotia's Pictou Harbour area, scientists are sampling juvenile mummichogs from areas of industrial and sewage outfalls and are quantifying the incidence of developmental abnormalities, such as spinal curvatures, relative to mummichogs from unimpacted sites. In the laboratory, mummichog embryos and larvae are being exposed to these industrial and municipal wastes to measure dose/response relationships. In Pictou Harbour, blue mussels are being caged within the influence of bleached kraft mill effluent and municipal waste water treatment plant effluent and monitored monthly for immune function.

Development of new indicators is only part of the story. Division scientists are exploring new ways of carrying out research and delivering science to local communities. The Pictou Harbour caged bivalve biomonitoring project is a collaboration between MESD, the local pulp and paper mill (Kimberly Clark Nova Scotia), the local sewage treatment plant (East River Pollution Abatement System), Environment Canada (Atlantic Coastal Action Plan), and the Pictou Harbour Environmental Protection Project. MESD scientists are also working closely with other scientists throughout North America to develop new frameworks for choosing indicators and then combining them to produce an overall assessment of environmental health. In the end, the goal of all of this work is to provide answers to the questions: "How healthy is our local marine environment, is it getting better or worse, and why?"

Continued involvement in research on the fate and effects of contaminants is required to address deficiencies in science and technology, to understand and predict the long-term cumulative effects of multiple contaminant sources, to foster methodological advances, and to ensure sound and cost-effective regulatory decisions regarding the mobilization of contaminants to the marine environment by society.

*A cage of blue mussels (*Mytilus edulis*) about to be deployed in Pictou Harbour.*

Canadian Imaging and Sampling Technology for Studying Marine Benthic Habitat and Biological Communities

Don Gordon Jr., Ellen Kenchington, Kent Gilkinson, David McKeown, George Steeves, Mark Chin-Yee, Peter Vass, Kelly Bentham, Kee Muschenheim, Tim Milligan, Cynthia Bourbonnais, and Kevin MacIsaac

Sustainable management of marine resources requires information on the classification and spatial distribution of benthic habitat and biological communities. During the past ten years, scientists and engineers at the Bedford Institute of Oceanography have designed and constructed a unique suite of specialized tools for imaging and sampling the seabed over different spatial scales. Three of these tools are briefly described below.

Towcam is a towed vehicle which collects continuous but low-resolution colour video imagery along transects many kilometers in length. It is towed at a speed of about 2 knots at an altitude (controlled by the winch) about 2 m off the seabed. The maximum working depth at present is 200 m. Real time video imagery is displayed in the ship's laboratory and on the bridge. Video imagery and navigation data are recorded for later analysis. Towcam has proven to be an excellent tool for conducting general reconnaissance surveys. Major habitat features such as sediment type, bedforms, fish, and large epibenthic organisms such as crabs, sea cucumbers, scallops, starfish and sand dollars (greater than about 10 cm) can be discerned from the video imagery. Towcam does not damage the seabed and has the potential to carry other sensors. It can be used over any kind of seabed (e.g. mud, sand, gravel, cobble, boulder, bedrock, etc.) as long as the relief is relatively low. Towcam has the potential to become an excellent stock assessment tool for commercial fisheries such as scallops.

Towcam.

Campod.

Campod is a light-weight instrumented tripod equipped with video and still cameras. Campod is deployed while the ship is stationary, or slowly drifting, and collects high-resolution colour video and photographic imagery from a small area. The Campod system includes laboratory controls, sliprings, a customized winch, approximately 500 m of conductor cable, and a large diameter block. During deployment and retrieval, a deck operator controls the winch. However, when the seabed comes into sight on the monitor, control of the winch is taken over by a scientist in the laboratory. The usual operating procedure is to slowly drift for a few minutes with Campod suspended just above the seabed to assess conditions and then land on features of particular interest to obtain higher resolution video imagery and take still photos. If current and wind conditions are suitable, it is possible to drift considerable distances (on the order of 500-1000 m).

Campod has proven to be an excellent tool for obtaining high-resolution video and photographic imagery of benthic habitat and epibenthic organisms. Except for the small footprint when it lands, Campod does not disturb the seabed. It can carry other equipment for benthic boundary layer studies such as optical backscatter sensors, a silhouette camera and a water sampler. Campod can be used over any kind of seabed (e.g. mud, sand, gravel, cobble, boulder, bedrock, etc.) regardless of relief, including steep walls of submarine canyons. Campod has proven very useful for studying the abundance and distribution deep-water corals.

Videograb is a hydraulically-actuated bucket grab equipped with video cameras. It was designed to minimize disturbance to the sampling area and allow the operator to visually select the precise sampling area on the seabed, close and open the bucket remotely, and verify that the bucket closed properly. The Videograb is deployed while the ship is stationary and uses the same laboratory controls, sliprings, winch, cable, and block as Campod. The usual operating procedure is to slowly drift for a few minutes and then land on features of particular interest. By paying out slack cable, the Videograb is decoupled from the motion of the ship and high-resolution video of the seabed is recorded looking through the open bucket during closure. If the operator is not satisfied with the landing site, if the Videograb tips over, or if the bucket does not close properly, the Videograb can be lifted off the seabed, the bucket opened hydraulically, and another landing site selected.

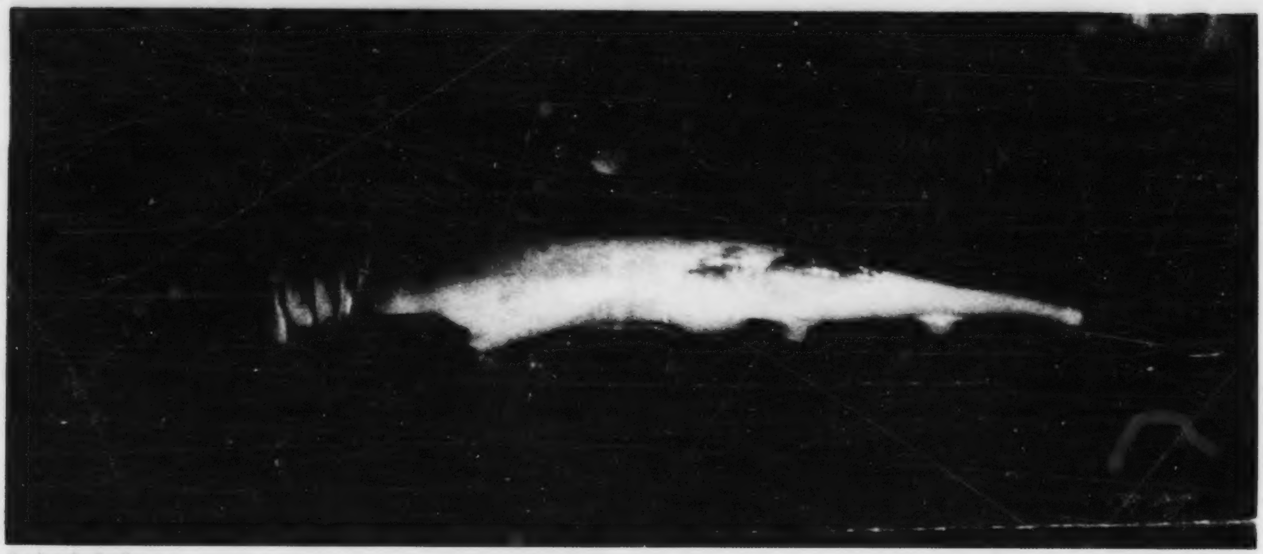
Videograb.

The Videograb has proven to be an excellent tool for collecting samples of sediment and associated organisms with minimal disturbance from a wide spectrum of sediment types ranging from mud to gravel. The associated video imagery provides information on the undisturbed habitat from which the sample is collected, as well as information on the quality of the sample. The Videograb was successfully used to recover wreckage from the Swissair crash site off Nova Scotia.

All three tools have been successfully used in studies of the effects of mobile fishing gear and hydrocarbon drilling wastes on continental shelf benthic ecosystems. They are now being used for mapping benthic habitat and communities at various locations off Nova Scotia including the Gully (a large submarine canyon just east of Sable Island) and the Northeast Channel (between Georges and Browns banks).

Biological Sciences

Shark Research Program - Steven Campana



Porbeagle shark.

Ever since the release of the movie *Jaws* in 1975, sharks have been viewed as the most dangerous and terrifying predators of the sea, a perception which had made them the preferred target of numerous sport fishermen around the world, and the scourge of many commercial fishermen. Now, 25 years after *Jaws*, many shark species around the world are in serious decline, some to the point of being endangered. A low birth rate, a low rate of natural mortality, and a delayed age at sexual maturation makes many shark species slow to replenish their numbers, and hence very sensitive to fishing-induced mortality. Although sharks are sometimes the target of a commercial fishery, more often they are merely an incidental by-catch of other fisheries, particularly those for tuna and swordfish. In an ironic turn of events, the apex predator of the ocean is now being threatened by the apex predator of the world – man.

The Shark Research Program at the Bedford Institute of Oceanography is responsible for research and stock assessment on the shark species found off the eastern coast of Canada, particularly those that are fished commercially or recreationally. Of the 14 shark species regularly found in our waters, three are now the subject of active research: the porbeagle, the blue and the basking shark.

Porbeagle shark are a poorly-understood species, closely related to the mako, and largely restricted to Canadian waters. An intensive research program on this shark is being carried out in collaboration with the Apex Predators Program of the U.S. National Marine Fisheries Service, in order to take advantage of the expertise of both laboratories. The support and funding of the Canadian porbeagle shark fishing industry also plays a significant role in the success of this research program, despite the fact that it is independent of any present or future fishing quotas. Despite being initiated only two years ago (in 1998), the program has already yielded the following results:

- Growth rings analogous to those of trees are formed yearly in porbeagle vertebrae, thus recording age and growth rate with considerable accuracy. The oldest porbeagle examined to date was 25 years old, and calculations suggest a longevity of more than 40 years.

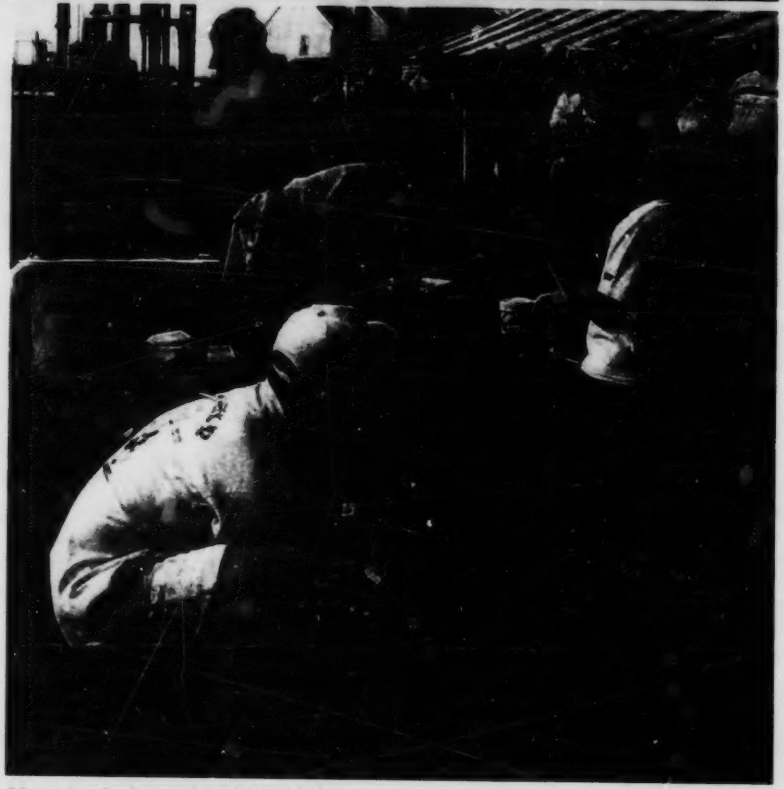
- Sexual maturity is reached only after many years – 14 years in the case of the females – and yields only 4 pups per year.

- Tagging studies have demonstrated that there is only one population in the northwest Atlantic, but that it moves up and down the continental shelf on an annual basis.

- Based on a detailed stock assessment in 1999, the current porbeagle population abundance is at 20% of its virgin level, due largely to overfishing in earlier years. The catch quota for 2000 has been set at 850 t, a level which is believed to be sustainable.

- Dietary studies indicate that the porbeagle is an active predator feeding on a diverse group of fish and shellfish throughout the water column. Marine mammals do not appear to be part of their diet.

Shark fishing derbies have been held in Nova Scotia each summer since 1994, and their popularity has increased each year. The species most often caught is the blue shark, although the occasional shortfin mako or porbeagle shark is also landed. Since blue sharks are caught, but seldom landed by the commercial fishery, derby catches are an important source of biological information on this species. Members of the Shark Research Program examine each shark landed at the derbies to determine length, weight, sexual maturity, stomach contents and to collect vertebrae for age determination, as well as record the amount of fishing effort required to catch the sharks. By monitoring trends in these data from year to year, the goal is to detect low stock abundance or overfishing in its earliest stages, as well as to develop an overall assessment of the general health of the population. While there are social and economic benefits to a recreational blue shark fishery, the blue shark population must be conserved at safe levels.



Measuring sharks at a shark fishing derby.

Basking sharks are large plankton feeding sharks with habits more similar to those of whales than to sharks. In some parts of the world, their populations are dangerously low, but little is known of their population status in Canadian waters. Although there is no fishery on these gentle giants, entanglements with nets and collisions with boats kill an unknown number each year. To provide an initial estimate of population size, the Shark Research Laboratory has enlisted the aid of local whale watching groups and sailing clubs and begun a long-term tagging program. Results are not expected for several years.

Section of porbeagle shark vertebra showing growth rings used for age determination.

For more information on Atlantic Canadian sharks and the Shark Research Program, please see the web site at www.mar.dfo-mpo.gc.ca/science/shark

Mako shark.

Traffic Light Indicators - Robert Mohn, Jerry Black, and Peter Koeller

Recent work on the Precautionary Approach to fish stock assessment and management has focused on the Traffic Light method of summarizing fisheries data. Traditional model-based methods of stock assessment have emphasized only those data that are suitable as input to the particular model used. The Traffic Light method is able to incorporate all data relevant to a stock assessment. This "holistic" approach to formulating management advice is similar to methods used in Environmental Impact Assessment. Traffic Light analyses were originally suggested only for use with "data poor" stocks, however, they may have a wider application. As well as marine fish resources, traffic lights are currently being used to assess all Atlantic Canadian shrimp stocks, including those of the Scotian Shelf.

In its simplest form, the traffic light method is just a way of summarizing all relevant data on a particular stock into a common format for easy review and comparison. These data are given a green, yellow or red light if the indicator suggests good, average, or bad stock status, respectively. One can then summarize the individual lights into an overall assessment of stock health. Ultimately, one would like to take this summary and translate it into management advice, such as changes to total allowable catches. However, before this can be done, the properties of traffic light analysis in general and its application to individual stocks have to be thoroughly examined. Marine Fish Division at BIO has developed a tool to allow fisheries scientists to do this.

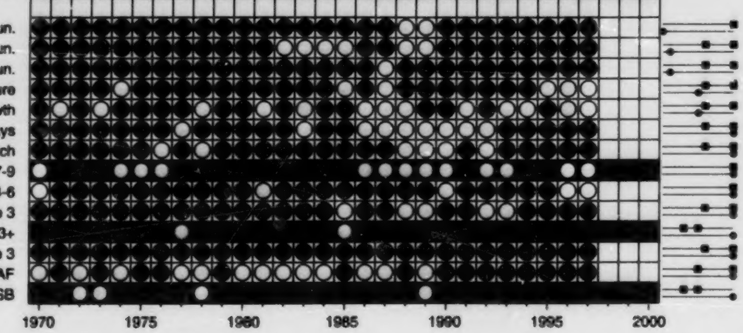
The following figure is an example for NAFO Division 4VsW cod from this interactive program. Note that the white circles are missing data. The program allows us to investigate the sensitivity of the overall summary to changes in the individual indicators. The two upper rows of lights are summaries of the data from the lower portion of the figure. The histogram shows the distribution of data for any indicator leading to the uppermost row of stoplights (labelled "overall"). In this example, it is showing the overall index. The other set of summary lights (labelled "danger") incorporates only the lights highlighted in light blue below.

The indicators in the lower portion of the figure have been grouped by type including quantitative model output, survey data from research vessels, fishery data (catch and effort), productivity-related factors (temperature and growth rate) and ecological data (prey, predator and bycatch species abundance). Each indicator has an associated histogram which is not shown but appears when clicking on the summary colour when using the program. Each row of lights also has three sliders on the right. Square sliders set the target and thresholds which in turn divide the data into the three colours. The circle sliders set the weight of the index in the overall summary shown in the top row. In the present version, these weights are constrained to four values, 0, 0.1, 0.5 and 1.

The limit sliders and weight sliders are set at arbitrary values, used only for illustration. For example, the importance of the ecologically related species is unknown, so their weights in the overall summary are 0 or 0.1. The limits in the upper histogram break it into regions of equal probability if the data were random. We see that in this example, the transition from green to red in the early 1990s was relatively sudden, only three years.

The program should facilitate discussion of a wider range of data and observations pertaining to stock status than has previously occurred. Most of the information in the figure is routinely available usually in quantitative form, e.g. Sequential Population Analysis model outputs. Some of the information may be reported in a narrative format, such as "temperatures have been falling in recent years". Even without weighting and overall summaries, the visual impact of the myriad indices can provide a subjective insight into stock status. Because of the interactive feature of the program, indices that are not important can be quickly identified and hopefully effort may be spent on more important signals.

Additional information on the approach is available from R.K. Mohn at mohnr@mar.dfo-mpo.gc.ca or from J. Black at blackj@mar.dfo-mpo.gc.ca

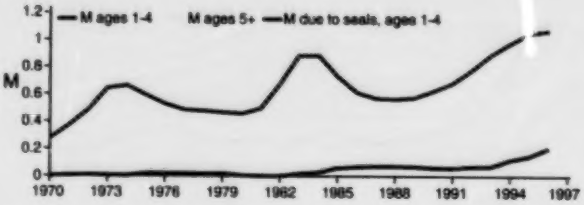


Traffic light indicators for 4VsW cod.

Comparative Dynamics of Exploited Ecosystems in the Northwest Atlantic: Ecosystem Modelling of the Eastern Scotian Shelf Shedding New Light on Mortality - Alida Bundy and Caihong Fu

In fisheries assessments it has been traditionally assumed that natural mortality (M) for species like cod is equivalent to 0.2, that is, about 20% of fish populations die naturally each year. The joke in fisheries science is that this originated from a fisheries scientist posing the question "M=?" As this question was scribbled a few more times in frustration, the "?" was transformed to a ".2", and fisheries management has been stuck with it ever since. Until 1986, M=0.2 was used in 4VsW cod assessments. Since then, M has been increased to 0.4 for the post 1986 period and in addition, predation by grey seals is explicitly included in the assessments, creating a two species, seal-cod model.

As part of the zonal ecosystem project entitled "Comparative Dynamics of Exploited Ecosystems in the Northwest Atlantic" (CDEENA), natural mortality is being explored using two methodologies. First, the seal-cod model has been revisited and turned on its head. Selectivity and catchability at age were fixed, and annual M estimated for two age groups, 1-4 and 5 and older. The figure clearly demonstrates that M is highly variable, and not constant at M = 0.2. The dramatic recent increases in M are not understood.



Variation in natural mortality of cod ages 1 to 4, and 5 and older, and predation monality due to seals for the 1 to 4 year olds.

In parallel with the above modelling work, the eastern Scotian Shelf ecosystem is being modelled with the mass balance model, Ecopath. Initial results from this second approach for estimating natural mortality also indicate that natural mortality exceeds 0.2. The table below contrasts the results from these two methods for the period 1980-1985:

			Natural Mortality Sources			
	Total Mortality	Fishing Mortality	Mortality due to Seals	Other Predation Mortality	Other Mortality	Total
Ecopath Estimates						
Adult Cod	0.63	0.40	0.003	0.001	0.22	0.22
Juvenile Cod	1.10	0.03	0.067	0.580	0.43	1.08
Juvenile Cod with Discards	1.10	0.37	0.067	0.576	0.09	0.73
Grey Seal/Cod Model						
Adult Cod	0.75	0.47	0.004		0.26	0.27
Juvenile Cod	0.68	0.04	0.026		0.62	0.65

An Atlantic cod caught by a DFO research survey - photo by Lei Harris.

Ecopath estimates of total mortality and total natural mortality are higher than the seal-cod model estimates for both adult and juvenile cod, while fishing mortality estimates are similar. For adults, fishing mortality either exceeds or is equivalent to total natural mortality. Precautionary management now suggests that optimum fishing mortality should not exceed 50% of natural mortality. Juvenile fishing mortality is apparently very low. However, both models predict a large unaccounted mortality during 1980-1985. If this is due to discards, then juvenile fishing mortality was much higher than previously estimated and was much greater than 50% of natural mortality.

The Ecopath model encompasses the whole living marine ecosystem. The above results are preliminary and may be updated as a result of other research being undertaken by the CDEENA project. Recent work on the estimation of catchability using meta-analysis, and applying the resulting catchability estimates to other species by analogy, has provided new biomass estimates for trawlable species. A comprehensive field program to collect and analyse stomachs is in its second year and is beginning to provide vitally important diet information. A new approach using fatty-acid analysis to estimate seal diets is also partly funded through CDEENA.

The overall aim of CDEENA is to gain a better understanding of the structure and function of eastern Canadian marine ecosystems. This is being accomplished through modelling, new fieldwork and analysis in order to address the question: "What have been the relative effects of fishing, trophic interactions and environmental variation on the population dynamics of marine finfish and shellfish inhabiting shelf ecosystems of the Northwest Atlantic?" For further information, please contact the Project Co-ordinator Paul Fanning at fanningp@mar.dfo-mpo.gc.ca

A young male grey seal – photo by Don Bowen.

Lobster Fisheries Management - Robert Miller

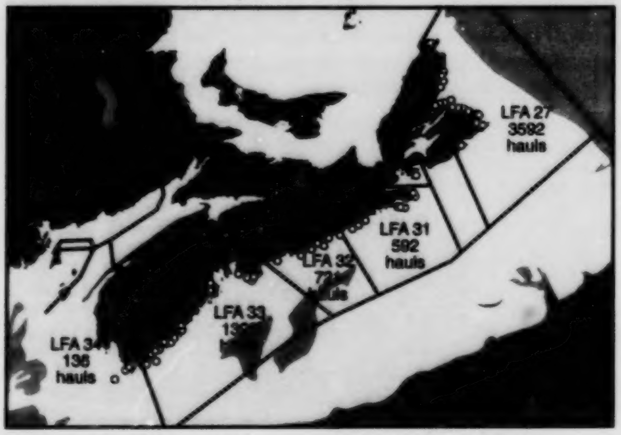
In the past two years biologists have become increasingly involved in fisheries management issues. The Marshall Decision by the Supreme Court has had a large impact on the lobster fishery and may result in the biggest changes in many years. Biologists have provided conservation rationales for fisheries regulations, the fishing effort required to supply food fisheries, and predicted impacts of summer commercial fisheries.

Following the Fisheries Resource Conservation Council report stating that lobster conservation needed to be strengthened, the DFO Minister gave instructions in late 1997 to double lobster egg production in all lobster fishing areas. Since then, biologists have been involved in developing and implementing methods to achieve this objective. Egg production is measured in eggs per recruit, the number of eggs an average commercial-sized female lobster produces in a lifetime, because there is as yet no practical method of measuring total egg production from an area. Eggs per recruit range from 500-6000 per individual lobster among areas in DFO's Maritime Region.

The benefits to eggs per recruit of several regulation changes were calculated; for example, identification of closed fishing areas and an increase in the minimum size limit in the fishery. In addition, measures to protect large females were assessed. These included a maximum legal size for females, a closed size interval for large females within the legal size range, and v-notching the tail of egg-bearing females taken in the catches and returning them to the water. The v-notching also protects them for a subsequent year when they are not egg-bearing.

Fishers have proposed other measures that have also been evaluated. These have included returning a set weight of mature females to the fishing ground to provide more brood stock, limiting the size of trap entrances to protect very large lobsters, and restricting other fisheries on lobster grounds.

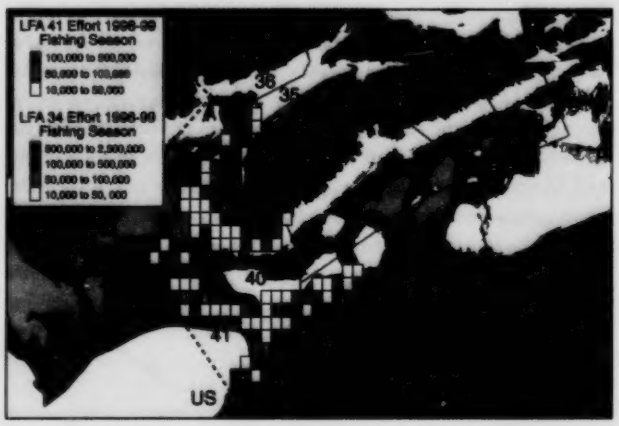
To date the following measures have been implemented: increases in minimum size, a maximum size for females, tail notching for females, and returning a specified weight of sexually mature females to the fishing ground. Evaluation suggests that the increase in minimum size has been the most beneficial. Enforcement is routine, weight yield is increased by taking lobsters at a larger size, and egg production is increased because more lobsters reach the size of sexual maturity.



Locations where fishers use Fishermen and Scientists Research Society traps - spring 1999.

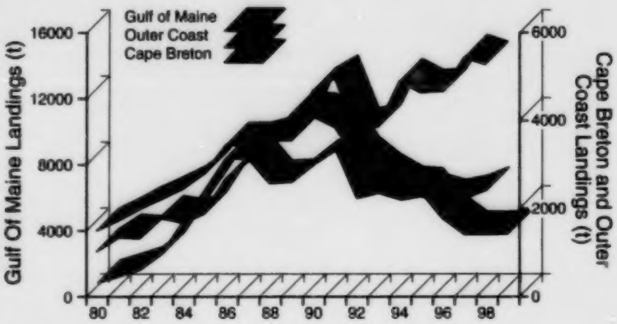
Fisher participation in fishery monitoring has increased. Throughout the region, volunteer fishers are recording sizes of lobsters caught in special small-mesh traps for possible use in predicting future catches. The Fishermen and Scientist Research Society (FSRS) has implemented this program.

In western Nova Scotia, fishers are providing their fishing locations which allow stock assessments to be more area-specific.



Lobster trap hauls per season in lobster fishing areas 34 and 41.

In recent years lobster landings have increased in the Gulf of Maine, changed little on the South and Eastern Shores, and decreased in Cape Breton. Biologists are concerned about stock sustainability in all areas because fishers are fishing smarter, and in some locations harder, with better navigation equipment, better traps, and bigger boats.



Landings (t)

CLAWS Contributions: Focus on Benthic Field Studies

John Tremblay and Peter Lawton

Canadian Lobster Atlantic Wide Studies (CLAWS) is an umbrella program for a series of projects designed to better understand some key aspects of lobster population biology, and the effect of the lobster fishery on these populations. Supported by DFO's Strategic Science Fund, CLAWS participants are from DFO Science labs in Quebec and Atlantic Canada, the Geological Survey of Canada (Atlantic), universities, the National Marine Fisheries Service (USA), and industry.

This article profiles benthic field studies conducted by Invertebrate Fisheries Division (IFD) staff under CLAWS. Other projects conducted under CLAWS by BIO staff are field and model studies of the distribution of lobster larvae (Ocean Sciences Div, Marine Environmental Sciences Div, and IFD) and development and enhancement of a population model ("eggs per recruit") that is used to provide advice on current conservation targets for the lobster fishery. Extended abstracts for all projects were tabled at the CLAWS Symposium in March 2000, and the symposium proceedings will be available in 2001.

Two CLAWS projects employed field studies of the benthic (bottom-dwelling) stages of lobsters. The Juvenile Lobster and Catchability projects used SCUBA and other sampling tools to answer questions about habitat relationships and the factors affecting the capture of lobsters by baited traps.

Quadrat to delineate the area for suction sampling used for measuring juvenile lobster density. This method of sampling involves suctioning the loose sediment into a bag. The bag contents are later searched for small lobsters.

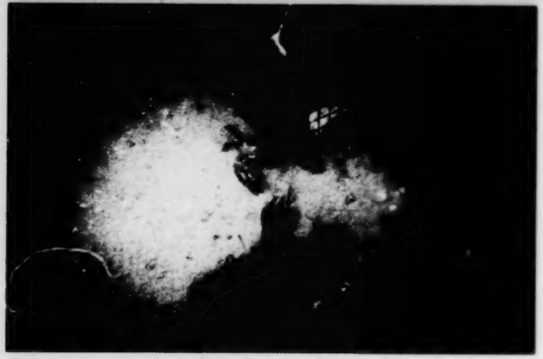
The Juvenile Project examined how juvenile lobster density and habitat varied at different spatial scales (centimetres to kilometres). The tools used include sidescan sonar, remote and diver-deployed video imaging, and physical sampling methods. This approach was applied to two geologically different regions in eastern Canada (Val Comeau, southern Gulf of St. Lawrence, and Lobster Bay, southwest Nova Scotia).

Habitat patches at the Val Comeau site were extremely complex and fragmented at large spatial scales. In contrast, in Lobster Bay, patch-sizes were large and fragmentation low. This region is made up of a diverse assemblage of habitats ranging from mud flats to shoals with large boulders originating from eroding mounds of glacial debris.

The Juvenile Project demonstrates that shallow coastal substrates are not homogeneous in their carrying capacity for juvenile lobsters. Coupled with new information on the geographic distribution of commercial catches of lobster, the approaches used in the Juvenile Project will contribute to the development of a spatially explicit lobster fishery production model.

The Lobster Catchability Project focussed on comparing the composition of trap catches with densities estimated from diving. Unlike many commercial fisheries, there are no fishery-independent surveys for lobsters. Therefore lobster biologists rely heavily on length measurements from commercial traps to assess the lobster stocks.

Juvenile lobsters collected by suction sampling.



Lobsters investigating a baited trap within one hour of setting.

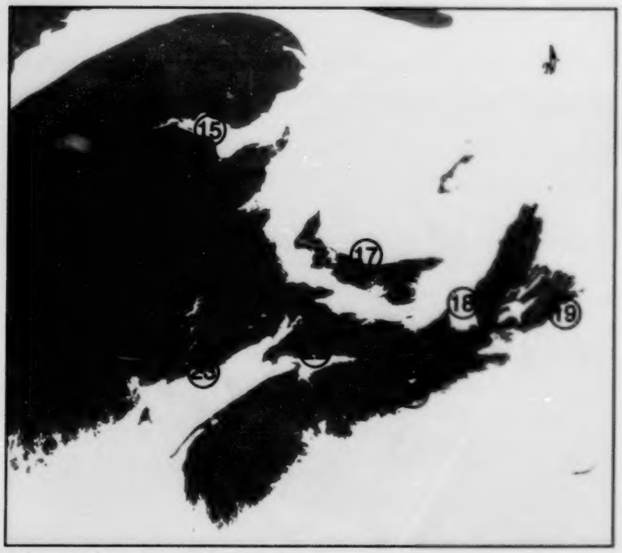
Lobster observed within 1 meter of the transect line used to measure density in the Catchability Project.

Most field studies were conducted in Lobster Bay, and the images of bottom type from sidescan sonar created under the Juvenile Project were used to select study sites. Lobster densities were estimated from dive transect surveys within 150 m by 200 m areas. Trapping was conducted following the diving.

The Catchability Project has demonstrated the importance of habitat and season to lobster catchability. Compared to a rougher bottom, lobsters were more likely to enter traps if they were on a simple mud or sand bottom with few boulders. Pre-recruit lobsters (those below the minimum legal size) were much more catchable in the spring, perhaps because the fishery had removed larger lobsters that inhibit pre-recruits from foraging and entering traps. These results have implications for how assessments are conducted, and how fishery-independent trap surveys are designed.

Regional Declines in Atlantic Salmon Abundance - Larry Marshall and Peter Amiro, in collaboration with Eric Verspoor

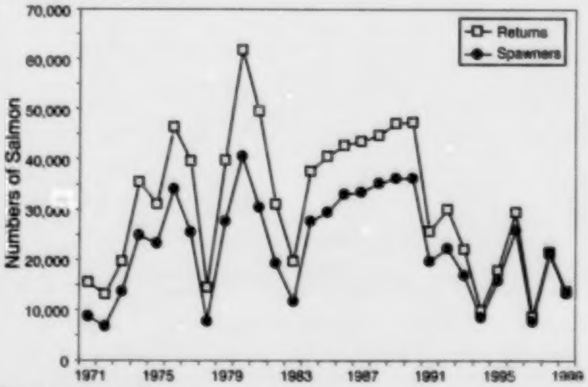
Within the Maritimes Region's Salmon Fishing Areas (SFAs) 19-23 there are more than 100 rivers which have supported Atlantic salmon. Declines in salmon within the last decade have resulted in closures of most rivers to recreational fishing. Homewater commercial fisheries for salmon ended in 1984; most distant-water fisheries were effectively closed in the early 1990s.



Salmon Fishing Areas - Maritime Provinces.

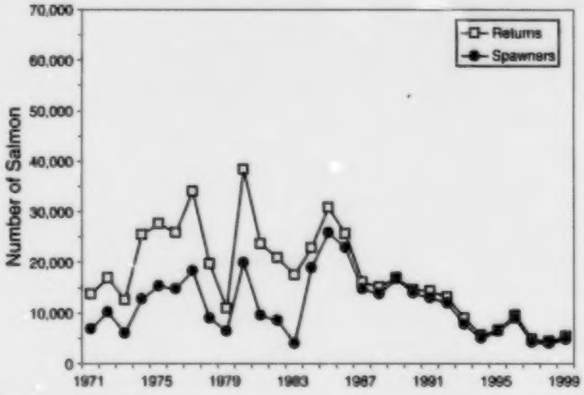
Spawning populations of rivers of the outer Bay of Fundy (portion of SFA 23) and the Atlantic coast of Nova Scotia (all of SFAs 19, 20 and 21) generally consist of 1-sea-winter (1SW) and multi-sea-winter (MSW) salmon. The MSW component is comprised of first-time and repeat-spawning fish. These stocks typically migrate to the Labrador Sea. Stocks of the inner Bay of Fundy (SFA 22 and a portion of SFA 23) typically mature as 1SW fish, have a high repeat spawning component and are not known to migrate to the Labrador Sea or to Greenland.

Estimated returns of salmon to rivers of the Maritimes Region, excluding the inner Bay of Fundy, have diminished from highs of 60,000 1SW fish in the late 1970s to current lows of approximately 10,000 1SW salmon.



One-sea-winter salmon.

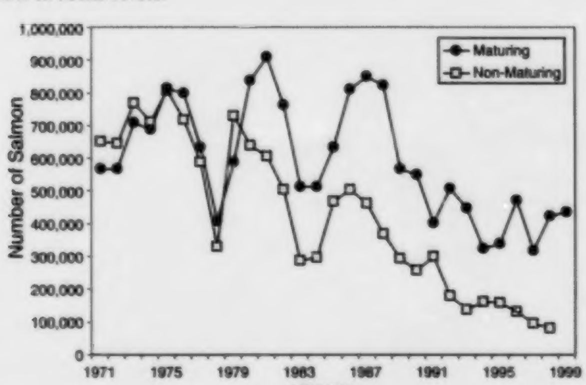
Two-sea-winter fish are an important component of total egg conservation requirement and have declined from about 40,000 to 5,000 salmon. Despite significant reductions in exploitation since 1984, 2SW fish now number only about 20% of the conservation requirements.



Two-sea-winter salmon.

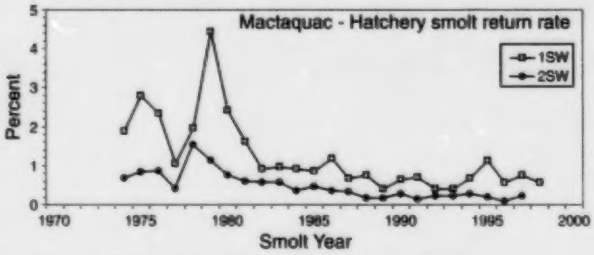
The declines in outer Bay of Fundy and Atlantic coast stocks are consistent with declines in the total estimated North American population of 1SW maturing and non-maturing (destined to be 2SW) salmon in the Labrador Sea. The at-sea pre-fishery abundance of returning North American salmon has declined from about 1.5 million in the early 1980s to about 0.5 million fish in recent years. Non-maturing 1SW fish have declined more rapidly than maturing 1SW fish resulting in fewer eggs per returning salmon.

Declines in North American Atlantic salmon stocks are generally attributed to reduced marine survival. Outer Bay of Fundy and Atlantic coast stocks have experienced reduced marine survival and are further impacted by anthropogenic effects, including acidification of some rivers.

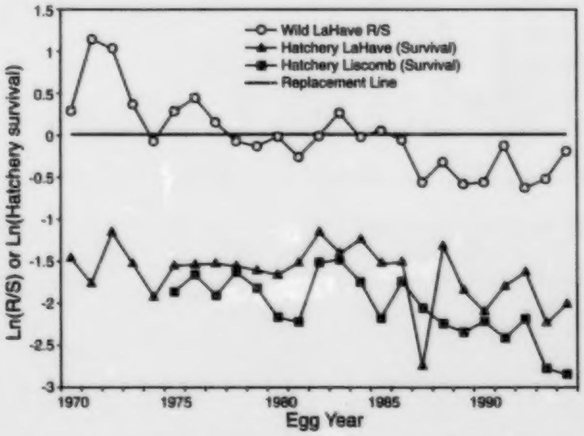


Pre-fishery abundance.

Reliable counts of salmon have been available at five permanent upstream monitoring facilities (Saint John River, Tusket River, LaHave River, East River Sheet Harbour and Liscomb) and two downstream monitoring facilities (Tusket River and LaHave River at Morgans Falls). Release of known numbers of hatchery-reared smolts proximate to the upstream facilities and enumeration of their returns has permitted the estimation of their marine survival. Marine survival of hatchery salmon to these facilities has trended downward since the mid 1980s.



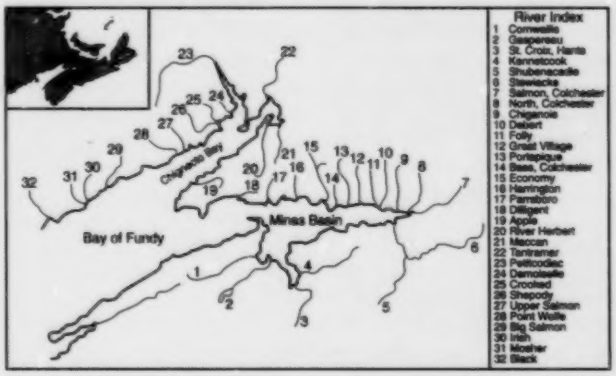
Return rates of hatchery smolts at Mactaquac, Saint John River, NB.



Wild returns per previous spawning escapement for the LaHave River and return rates of hatchery smolts as 1SW fish on the LaHave and Liscomb rivers, NS.

The above trend in wild LaHave recruit per spawner (R/S) is consistent with the downward trends in marine survival of hatchery-origin fish.

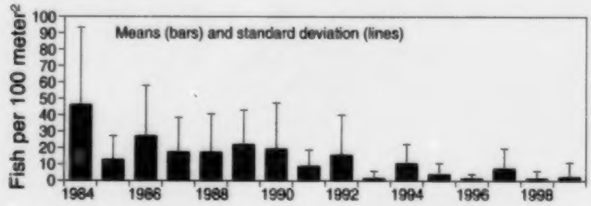
Stocks of the inner Bay of Fundy have declined 90% or more since 1985, probably number fewer than 500 fish and are at risk of extinction. Rivers tributary to the inner Bay have a variety of habitats and are well suited to the production of salmon. Since 1985 no widespread degradation of freshwater habitat is known to have oc-



Inner Bay of Fundy rivers.

curred. Reduced marine survival is believed to be the principal reason for the decline. Interactions between wild and farmed Atlantic salmon may have an effect on the total Bay of Fundy complex but have as yet to be documented.

Although the stock has historically varied in abundance, the recent decline is more severe and the population is at a lower abundance than previously documented. Monitoring of juvenile salmon in the two largest rivers, Stewiacke River and Big Salmon River, as well as in six other rivers of the inner Bay of Fundy has confirmed that the decline is severe and extensive. River-specific population extinction has also been noted.



Age-0$^+$ (fry) salmon monitored in the Stewiacke River, 1984 to 1999.

Divers sampling one of the few Atlantic salmon spawners in an inner Bay of Fundy River.

Annual recruitment to spawning of inner Bay of Fundy salmon stocks is not correlated with other Atlantic coast salmon populations. Genetic research into the phylogenetic structure of surveyed inner Bay of Fundy river stocks revealed the presence, at moderate frequency, of a restriction-enzyme detectable DNA variant which is, in fact, absent from stocks elsewhere in North America and Europe. Analysis of mitochondrial DNA (mtDNA) further suggests the existence of Chignecto Bay and Minas Basin as evolutionarily defined populations within the inner Bay of Fundy.

Initiatives to preserve some dwindling stocks and to address concerns that the salmon farming industry has the potential to negatively impact wild stocks of the Bay of Fundy are ongoing. Efforts by DFO in partnership with other government and non-government agencies include live gene banking and mating of threatened stocks, genetic surveys of diminishing salmon stocks, improved monitoring in freshwater, and tracking of post smolts in the Bay of Fundy.

Fence and trap for capturing adult salmon returning to the Nashwaak River, New Brunswick.

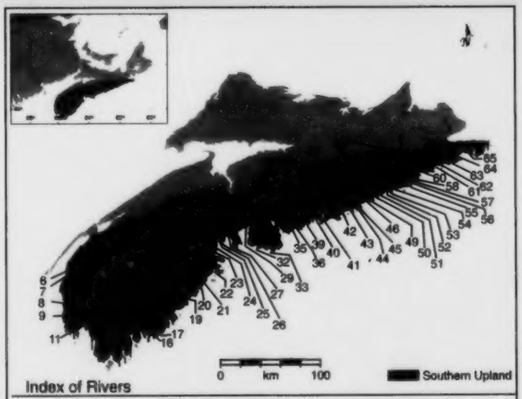
Acid Rain and Atlantic Salmon - Peter Amiro

Low marine survival and acidification have adversely affected the potential for sustainability of natural reproducing Atlantic salmon in many rivers which have their source in the Southern Upland of the Atlantic coast of Nova Scotia. Many river stocks are already extirpated and projections suggest that if the present trend of low marine survival continues, about 47 of the 65 rivers will soon be without Atlantic salmon.

The Southern Upland of Nova Scotia is characterized by lowland areas of shallow soils and peat bogs underlain by granites and metamorphic rocks lacking in base minerals. The water of these rivers is generally organic-acid stained, easily acidified, and when combined with acid precipitation can become toxic to salmon. Interspersed throughout the Southern Upland are pockets of limestone rich soils (drumlins) that provide local areas where river conditions are less acidified.

Sulfur dioxide (SO_2) emissions (from metal smelting and coal-fired electrical utilities) and nitrous oxide (NO_x) emissions from combustion are the principal acidifying pollutants. They are transported over half a continent and fall as acids in the precipitation.

In Nova Scotia, the principal acidifying agent in the precipitation is sulfate. North American emissions of SO_2 increased during the industrial revolution, peaked in the early 1970s and have since declined with acceptance by industry of emission standards. Reductions in sulfate depositions did not result in improvements to water quality (increased pH) in Nova Scotia lakes or rivers because much of the soil buffering capacity has been expended.

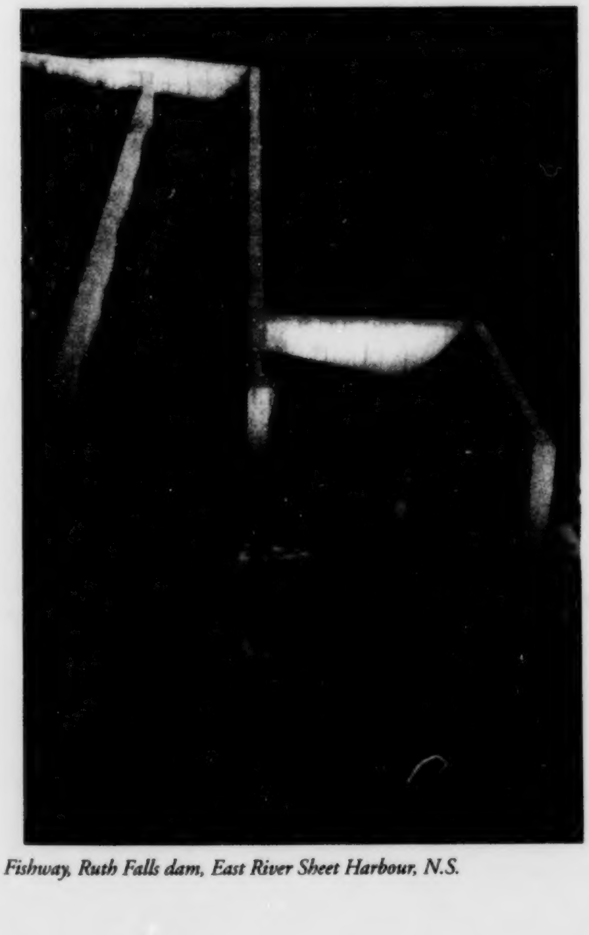


Index of Rivers

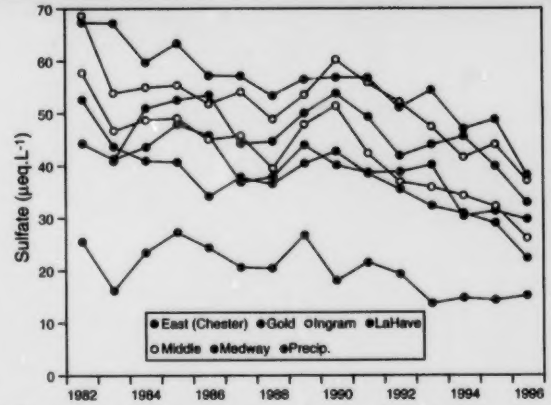
1 Nictaux
2 Round Hill
3 Bear
4 Sissibo
5 Belliveau
6 Boudreau
7 Meteghan
8 Salmon (Digby)*
9 Annis
10 Tusket*
11 Argyle
12 Barrington*
13 Clyde*
14 Roseway*
15 Jordan*
16 East
17 Sable*
18 Tidney
19 Mersey
20 Medway*
21 Petite*
22 Lahave*
23 Mushamush*
24 Martins*
25 Gold*
26 Middle*
27 East (Chester)*
28 Little East
29 Ingram*
30 Indian
31 East
32 Nine Mile*
33 Pennant
34 Sackville*
35 Salmon (L Major)*
36 Salmon (LEcho)*
37 West Bk Porters*
38 East Bk Porters*
39 Chezzetcook*
40 Musquodoboit*
41 Salmon (Hfx)*
42 Ship Harbour*
43 Tangier*
44 E Taylor Bay*
45 W Taylor Bay*
46 Little West
47 West (Sh Hbr)*
48 East(Sh Hbr)*
49 Kirby*
50 Salmon (P.D.)*
51 Quoddy*
52 Moser*
53 Smith*
54 Ecum Secum*
55 Liscomb*
56 Gaspereau Bk*
57 Gegogan*
58 St Marys*
59 Indian Harbour Lakes
60 Indian*
61 Country Harbour*
62 Issacs Harbour*
63 NewHarbour*
64 Larrys*
65 Cole Harbour*

*One of the 47 rivers used in the impact analysis

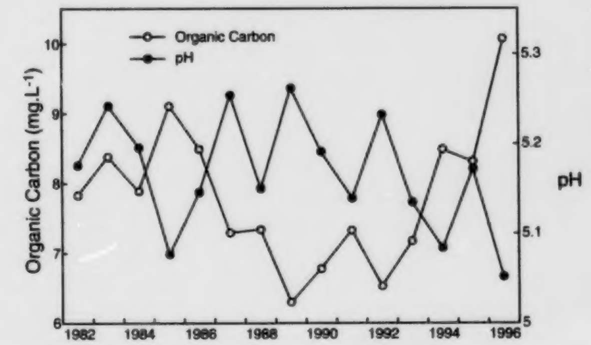
Rivers of the Southern Upland of Nova Scotia.



Fishway, Ruth Falls dam, East River Sheet Harbour, N.S.



Sulfate levels on six rivers of the Southern Upland, 1982-1996.



Average pH and organic carbon levels for six Southern Upland rivers, 1982-1996.

Mortality of salmon due to exposure to low pH in freshwater varies with the life stage. All freshwater stages are unaffected at pH above 5.4; no stages survive below pH 4.7. Levels of pH≤5.0 have also been shown to interfere with the smolting process and sea water adaptation.

Increased hydrogen ion concentrations coupled with the low concentrations of calcium are responsible for the mortality of salmon in acidified rivers of Nova Scotia. Concentrations of dissolved organic carbon (5-30 mg. L^{-1}) and total dissolved aluminum (100-350 µg. L^{-1}) are high but bind to form organic aluminum complexes which, unlike the inorganic forms, are not toxic to fish.

Significant reductions in acid toxicity for salmon are not anticipated in the near future. Further declines in salmon production and losses of salmon stocks are expected, unless marine survival improves significantly.

Management options under consideration to protect remaining salmon stocks include: liming to neutralize river acidity and restore some habitat production capacity; stocking of hatchery-reared fish to increase salmon returns; live gene banking to preserve stocks and support future restoration; and restricting exploitation.

Research Voyages - David L. McKeown

The Canadian Coast Guard Ship (CCGS) *Alfred Needler* is a 50m offshore fisheries research trawler. During the 2000/01 field season it was employed by scientists from the Bedford Institute of Oceanography, Gulf Fisheries Centre and Institut Maurice Lamontagne to conduct offshore finfish and shellfish ecosystem trawl surveys and related research programs on the Scotian Shelf from Georges Bank to Cabot Strait and into the Gulf of St. Lawrence.

CCGS Alfred Needler.

CCGS *Hudson* is a 90m offshore research and survey vessel. During the winter of 1999/2000, the vessel completed the first phase of an extensive refit to prolong its working life another seven to ten years. Consequently, it did not start its 2000 field season until mid-May.

CCGS *Parizeau* was used to meet program requirements prior Hudson's return to service. At the beginning of April she commenced the first phase of a cruise to collect physical and biological oceanographic data for the Atlantic Zonal Monitoring Program (AZMP). This annual spring survey encompassed a series of survey lines across the Scotian Shelf from southern Nova Scotia to Cabot Strait. After a brief and unplanned stint on fisheries conservation and protection duties, CCGS *Parizeau* went to the southern edge of the Grand Bank to service some oceanographic moorings and then returned to the Scotian Shelf to complete the spring AZMP survey.

CCGS Parizeau.

CCGS Hudson.

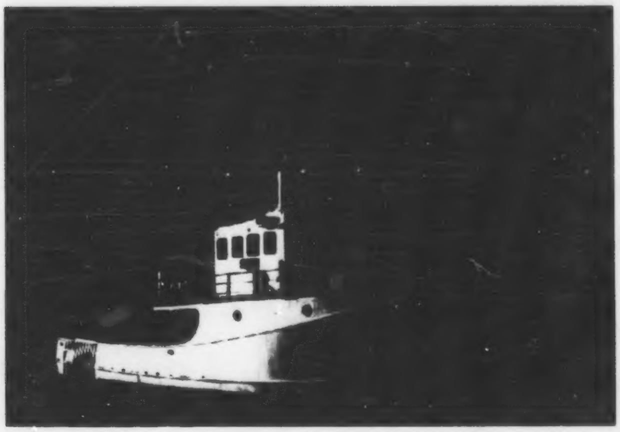
In mid-May CCGS *Hudson* resumed her role as the main oceanographic research platform in the Atlantic Zone. She first journeyed to the Labrador Sea to service oceanographic moorings and conduct hydrographic (conductivity/temperature/depth) survey operations as part of Canada's contribution to global climate studies. After returning to BIO to change staff and re-configure equipment, the ship sailed to the Hibernia field on the Grand Bank to collect information on the impact of drill waste on benthic organisms. It then returned to the Scotian Shelf to support benthic habitat surveys at Banquereau, the Gully, Northeast Channel and the Swiss Air site. The vessel was then reconfigured to do a number of geophysical survey operations on the Scotian Shelf and Slope during the summer months. In late September, the autumn AZMP cruise was carried out. This was followed immediately by an AZMP survey conducted by staff of the Northwest Atlantic Fisheries Centre off the Newfoundland coast. After servicing oceanographic moorings on the southern edge of the Grand Banks, the vessel proceeded to the Gulf of St. Lawrence to provide a platform for AZMP surveys being carried out by staff of the Institut Maurice Lamontagne. When

CCGS Matthew.

the vessel returned to BIO after that activity, it began the second phase of the life extension refit.

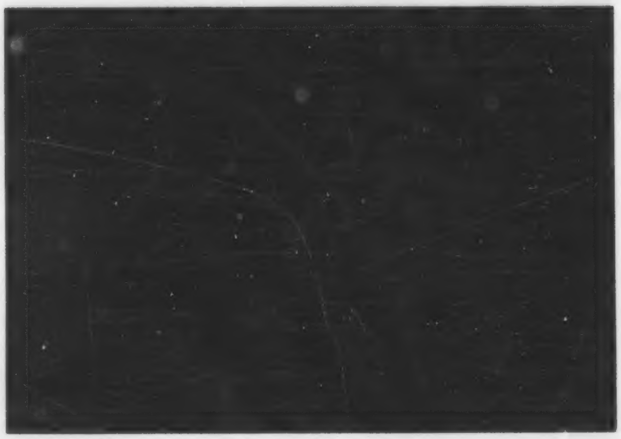
CCGS *Matthew* is a 50m coastal research and survey vessel. The season began in May when a group of Dalhousie University oceanographers used the vessel to undertake a fisheries biological survey on the Scotian Shelf. At the beginning of June the vessel proceeded to the south coast of Newfoundland to commence a hydrographic charting program. In early August hydrographic charting activities moved to the Labrador Coast. The vessel returned to BIO in early October. After being re-configured with geophysical equipment, it carried out surveys in the Saint John, N.B. and Liverpool, N.S. harbour areas.

The Maritimes Region also operates several smaller inshore fisheries research trawlers. These vessels are used by a large number of scientists who conduct a wide-ranging scientific program including stock assessment, fisheries and habitat research and geophysical surveys. CCGS *J.L.Hart* (20m), operating out of the St. Andrews Biological Station, spent most of the 2000 season supporting research programs in the Bay of Fundy area. The CCGS *Opilio* (18m), based in Shipigan, New Brunswick, enabled staff of the Gulf Fisheries Centre to carry out research programs in the Northumberland Strait and in the Bay of Chaleur area. The CCGS *Navicula* (20m) served as a platform for a cooperative DFO/First Nations fisheries research program in the Bras d'Or Lakes as well as supporting a number of other fisheries and habitat research programs in the Bay of Fundy and Cape Breton coastal areas of Nova Scotia. The CCGS *Pandalus III* (13m) operating out of the St. Andrews Biological Station conducted numerous daily trips in the local area throughout the year.

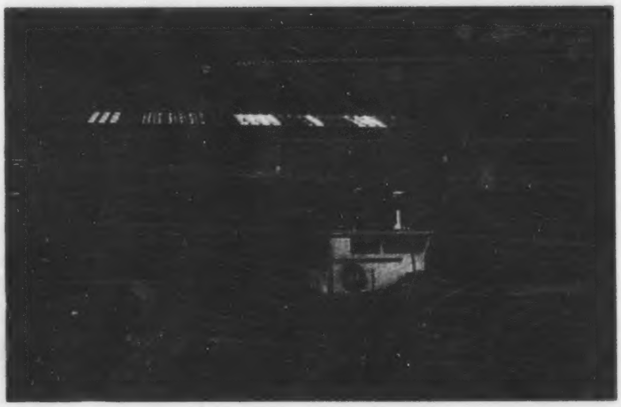


CCGS J.L.Hart.

CCGS Navicula.



CCGS Opilio.



CCGS Pandalus III.

CROSS CUTTING ISSUES

Maritimes Aquatic Species at Risk Act Office

John Loch (Fisheries and Oceans Canada)

In February 2001, the Federal Government will table Bill C-5, a *Species at Risk Act* (SARA), intended to help species at risk of extinction in Canada to recover to sustainable levels. The proposed *SARA* provides the authority to prohibit the destruction of endangered or threatened species and their critical habitat on all lands and in all waters in Canada. It is expected that the Bill will be passed into law by the spring of 2002.

The legislation is a three-pronged Strategy for Species at Risk: the *SARA*, the federal/ provincial/ territorial *Accord for the Protection of Species at Risk*, and the *Habitat Stewardship Program*. This strategy will bring considerable responsibilities to DFO and to the Maritimes in particular. At this time, the North Atlantic right whale, the leatherback turtle, and the Atlantic whitefish have all been identified as "endangered" by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). In addition, COSEWIC considers the harbour porpoise as "threatened", and it is anticipated that COSEWIC will list inner Bay of Fundy Atlantic salmon as "endangered" within the next few years. To coordinate the requirements under the act, DFO established the Maritimes Aquatic Species at Risk Office at BIO in 2000.

Actions prescribed by the anticipated *SARA* and by the existing *Accord* will involve considerable consultations with stakeholders in the fishing and marine industries as well as with aboriginals. In addition to these interested parties, DFO needs to co-ordinate its activities with other government agencies both nationally and internationally who have their own species at risk legislation and policies. Consultations and co-ordination on actual "recovery planning" will be required involving stakeholders and other interested parties to recover endangered and threatened species to sustainable levels. A plan has already been established for North Atlantic right whale in co-operation with the World Wildlife Fund and other partners in the fishing and marine services industry. Recovery teams have been, or will be, formed for the other species mentioned above. Other key activities arising from the strategy include: enforcement of the *SARA* and/or the *Fisheries Act*, assessment and monitoring of the status of species at risk, protection of their critical habitat, management of species of special concern, establishment of agreements, permits and exemptions, and emergency orders.

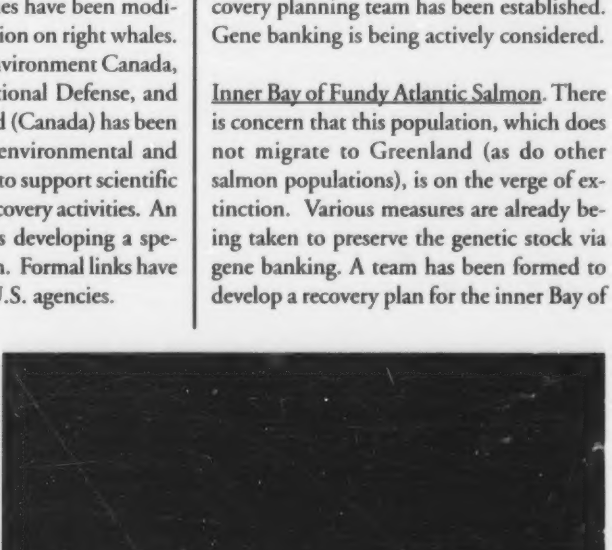
Accomplishments during the past year:

North Atlantic Right Whale. A recovery strategy has been developed in conjunction with various partners in the fishing and marine services industries as well among environmental organizations, most notably the World Wildlife Fund (Canada). Nautical charts for the relevant areas of the Bay of Fundy and its approaches have been modified to include information on right whales. Funding from DFO, Environment Canada, the Department of National Defense, and the World Wildlife Fund (Canada) has been distributed to various environmental and academic organizations to support scientific communications and recovery activities. An implementation team is developing a specific remedial action plan. Formal links have been established with U.S. agencies.

Leatherback Turtle. The distribution of these turtles in Canadian waters is being studied by Dalhousie University. Additional research and assessment is needed regarding estimates of current by-catch of marine turtles in various fisheries along the Atlantic coast in Canada and the United States. A workshop will be held early in 2001 to address this matter. Questions remain regarding seasonal movements of the turtles and their vulnerability to fishing gear. Funding from Environment Canada will help publicize the plight of this animal. By May 2001, recovery planning will have started. Formal links have been established with U.S. agencies.

Atlantic Whitefish: A multi-year research program has been launched by DFO on the population biology and habitat requirements of this fish in the waters of Nova Scotia. Significant numbers of the fish in landlocked form have been located in only one watershed (Petite Rivière near Bridgewater, NS). No anadromous whitefish have been seen or captured. It would appear that competition with smallmouth bass along with habitat constraints constitute the major threats to this species. A recovery planning team has been established. Gene banking is being actively considered.

Inner Bay of Fundy Atlantic Salmon. There is concern that this population, which does not migrate to Greenland (as do other salmon populations), is on the verge of extinction. Various measures are already being taken to preserve the genetic stock via gene banking. A team has been formed to develop a recovery plan for the inner Bay of



Right whale mother and calf - photo by the New England Aquarium.

Leatherback turtle.

Fundy salmon. DFO initiated a status review of this "metapopulation" and has submitted it to COSEWIC for status designation.

Lake Utopia Dwarf Smelt. This is a species listed by COSEWIC as threatened. Joint work is being planned with the New Brunswick government to further research, assessment activities, and recovery planning.

Harbour Porpoise. DFO has been monitoring the by-catch of this species in the fisheries of the Bay of Fundy. Due to increased involvement of fishermen and the introduction of acoustic warning devices on gill nets, by-catch has dropped considerably over the past seven years. As a result of updated information regarding by-catch, population estimates, and genetic information, DFO is supporting a reassessment of this species by COSEWIC. In addition, an Atlantic-wide zonal recovery approach is being launched along with coordinated research.

Harbour porpoise - photo by John Wang.

SeaMap - Discovering Canada's Next Frontier

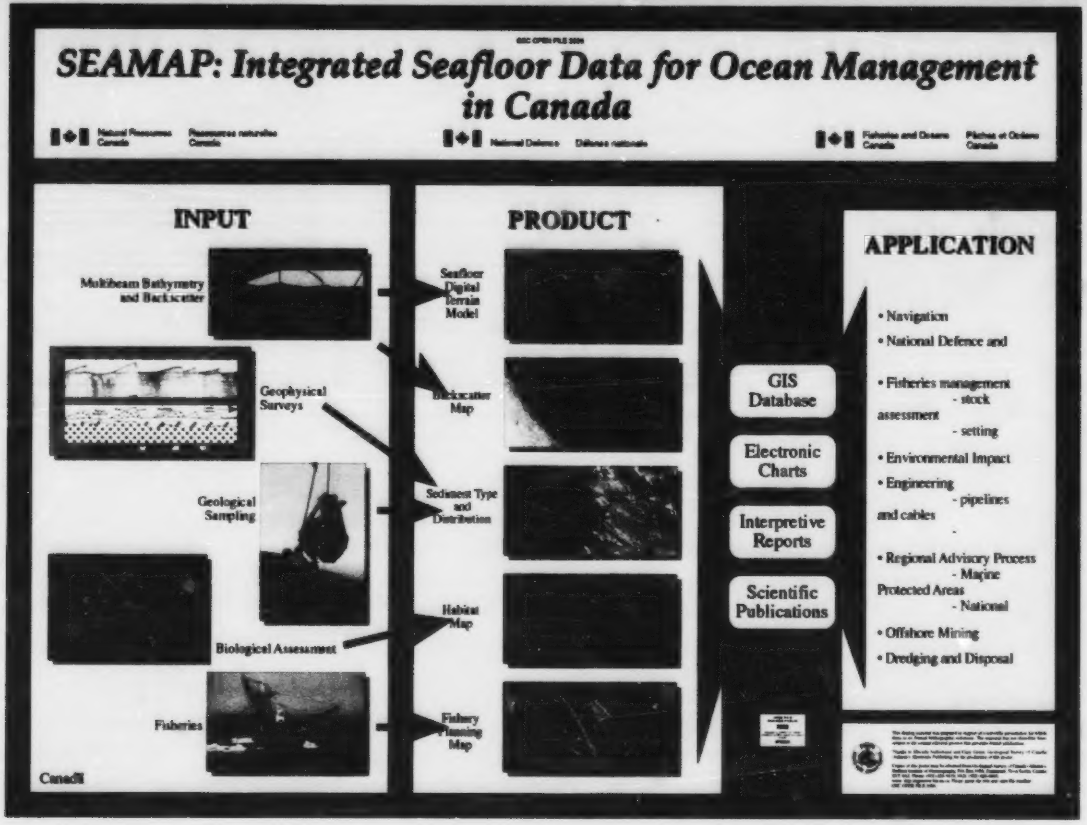
Richard MacDougall (Canadian Hydrographic Service [DFO]), **Richard Pickrill** (Geological Survey of Canada, (Atlantic) [NRCan]), **Jim Bradford** (Route Survey Office [DND]), and **Don Gordon** (Marine Environmental Sciences [DFO])

For the past year, the Bedford Institute of Oceanography (BIO) has been home to the project office for SeaMap, the Canadian Seabed Mapping Program, supported by three lead departments: Fisheries and Oceans (DFO), National Defence (DND) and Natural Resources Canada (NRCan). The SeaMap concept proposes to systematically create a base-map data set for Canada's submerged lands which combines seabed shape, sediment, and plant and animal life. Such a data set for our three oceans and the Great Lakes is seen as basic infrastructure for sustainable development and the integrated management of seabed resources and ecosystems. The Project Office was set up by the SeaMap Steering Committee, made up of national representatives from each of the three lead departments and was tasked with developing a business case, an implementation plan, and a funding proposal for establishing SeaMap as a new national initiative.

The SeaMap concept grew from collaborations among researchers at BIO, the Ocean Mapping Group of the University of New Brunswick, service industries, the fishing industry, and most recently, the offshore oil and gas industry. These projects resulted in the University of New Brunswick being considered a world leader in multibeam mapping theory, analysis and applications, and the Canadian Hydrographic Service (CHS) and the Geological Survey of Canada Atlantic (GSCA) leaders in integrating the technologies. This collaborative synergy became visibly evident in the rapid and efficient response of these partners to the Swiss Air 111 tragedy. Also, these collaborations have resulted in a unique combination of many techniques, including seabed mapping using multibeam technology, seismic, side scan sonar, and video ground truthing to produce bottom shape, seabed sediment, and habitat maps that provide substantive economic and environmental benefits to Canada.

As an example, the offshore scallop industry recently partnered with the Canadian Hydrographic Service and the Geological Survey of Canada Atlantic in a project to map and develop interpretative techniques specifically for this industry. Through this collaboration, accurate scallop habitat maps were produced on Browns and German banks. Using these new techniques, the scallop industry was able to achieve a 70% reduction in time on bottom and a 40% reduction in fuel consumption. This resulted in cost savings to the industry, and perhaps more importantly, to a large reduction in the environmental impact of scallop dragging. This successful partnership prompted the scallop industry to outfit a multibeam vessel to map the Canadian portion of Georges Bank. The vessel has also been used to map areas of the Scotian Shelf for other applications, including petroleum exploration needs and for environmental protection.

The SeaMap proposal includes a comprehensive plan to systematically map all of the submerged lands of Canada. This plan was developed through targeted studies and from national consultations. A series of workshops were held across Canada (St. John's, NF; Halifax, NS; Quebec, QC; Burlington, ON; and Sidney, BC). These workshops provided key input from SeaMap stakeholders, including potential industry partners who need the results, service providers who could help to deliver the program, provinces, universities, and non-government organizations. The meetings affirmed that SeaMap is an important national initiative for all stakeholders. The technology is available, the infrastructure to support SeaMap can be developed, and the user community exists to benefit from it. In addition to the workshops, a number of studies were completed that defined program costs, geographic limits, water depth limits, as well as the program's benefits to Canada.



GSC OPEN FILE 3906

SEAMAP: Integrated Seafloor Data for Ocean Management in Canada

Natural Resources Canada / Ressources naturelles Canada
National Defence / Défense nationale
Fisheries and Oceans Canada / Pêches et Océans Canada

INPUT

- Multibeam Bathymetry and Backscatter
- Geophysical Surveys
- Geological Sampling
- Biological Assessment
- Fisheries

PRODUCT

- Seafloor Digital Terrain Model
- Backscatter Map
- Sediment Type and Distribution
- Habitat Map
- Fishery Planning Map

GIS Database
Electronic Charts
Interpretive Reports
Scientific Publications

APPLICATION

- Navigation
- National Defence and
- Fisheries management
  - stock assessment
  - setting
- Environmental Impact
- Engineering
  - pipelines and cables
  -
- Regional Advisory Process
  - Marine Protected Areas
  - National
- Offshore Mining
- Dredging and Disposal

If approved, SeaMap would provide, through strong partnerships with industry and universities, images, maps and data of the seabed shape, sediment, habitat and biological communities of Canada's submerged lands using the unique integration techniques developed by BIO researchers over the past ten years. These data and maps would be widely accessible for sustainable ocean and lakes management and for public participation in decision making.

Background documents, summary information, and highlights from recent workshops can be obtained by visiting the SeaMap web site at http://SeaMap.bio.ns.ca.

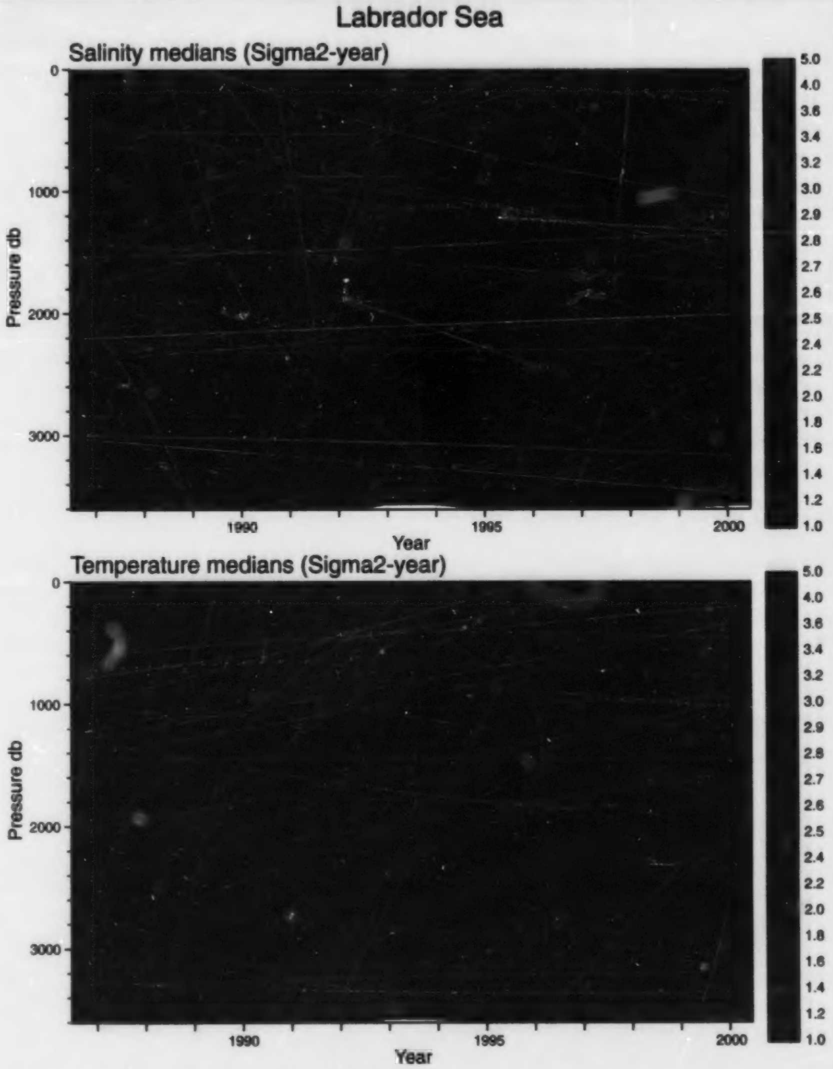
Copies of the SeaMap poster are available on request from GSC (Atlantic) as GSC open file 3906.

Climate Change and Variability - Allyn Clarke (Ocean Sciences [DFO])

Climate change and variability is a coordinating theme for a significant part of the physical and biological oceanographic programs of the Ocean Sciences Division. Oceanographic data, collected over the waters of Atlantic Canada since the late nineteenth century, have been brought together into a regional ocean climate database. At the moment, this database contains only temperature and salinity information; nutrient, and oxygen concentrations are in the process of being added. Eventually, biological information will also be included. The database is being constantly updated as new observations are collected and processed. It is a primary tool for exploring the climatology of the Northwest Atlantic and can be queried from the Ocean Sciences Division's web site: http://www.mar.dfo-mpo.gc.ca/science/ocean/welcome.html

Ocean colour observations from the SeaWifs satellite have allowed us to map Chlorophyll-a concentration, primary productivity, and sea surface temperature semi-monthly for the entire Northwest Atlantic since September 1997. These data products are being used to describe the seasonal cycle of phytoplankton over all of Atlantic Canadian waters in order to understand and model how they respond to the physical environment and interannual variability. These products are also available on the Division's web site: http://www.mar.dfo-mpo.gc.ca/science/ocean/ias/seawifs/seawifs_3.html

Already, the first three years of data are exhibiting important year to year changes in the timing and strength of the spring phytoplankton bloom over the entire region. We are exploring these differences through analyses and models. When oxygen, nutrient and biological parameters are added to the regional ocean climate database, mod-



Changes in salinity and temperature in the Labrador Sea.

els will allow these analyses to be extended back in time before the launch of SeaWifs and to assess how the primary productivity driving our marine ecosystems has changed over the past decades.

It is only over the second half of the twentieth century that sufficient high quality ocean data have been collected to document the strong variability in the ocean environment of Atlantic Canada. The sparser data sets of the late nineteenth and first half of the twentieth century suggested that the extreme cold conditions of the 1990s and the warm conditions of the 1960s both occurred earlier during the past twelve decades. These events appear broadly linked to the North Atlantic Oscillation, a mode of climate variability centred over the northern North Atlantic. Its positive phase is associated with a strong winter low pressure region situated over Iceland. This results in strong cold northwesterly winter winds over Labrador, increased growth of sea-ice and cold dense waters over the Labrador and Newfoundland shelves.

The 1990s were a period of sustained high positive North Atlantic Oscillation Index as well as sustained El Nino in the tropical Pacific. Both these of climate signals resulted in extreme conditions in the Northwest North Atlantic. Climate scientists are examining whether this behavior of climate variability is a rare but natural occurrence or a result of climate change. Climate scientists had believed that climate variability with periods of years to decades had to arise from the interaction of the ocean with the atmosphere because only the ocean had sufficient heat capacity to retain climate anomalies from year to year. However, a close examination of the correlation between oceanic and atmospheric temperatures suggests, that for the case of the North Atlantic Oscillation, the atmosphere is driving the ocean.

In June 2000, CSS *Hudson* began a second decade of an annual occupation of an oceanographic section across the Labrador Sea from Hamilton Bank to Southwest Greenland. The section measures how much water has been transformed to intermediate and deep water through winter cooling and convection both in the Labrador Sea and also in the Nordic seas north of Iceland. Winter convection in the high latitude North Atlantic drives a global overturning circulation known as the Meridional Overturning Circulation. This circulation plays an important role in maintaining our current climatic state; its variation through geological time is thought to result in the earth's climate changing from inter-glacial to ice age conditions. Observing this system's interannual changes will permit this phenomena to be accurately captured by ocean and climate circulation models.

Deep winter mixing also plays important roles in the sequestering of carbon dioxide and other radiatively active gases. Convection physically transports gases from the atmosphere first to the surface ocean and then to the deep ocean where it remains isolated from the atmosphere for periods of decades to centuries. Winter convection also establishes high surface nutrient concentrations to support strong primary and secondary biological productivity in the spring. This biological productivity leads to a sequestering of carbon into the deep ocean through the sinking of biological particles containing carbon out of the surface layer. These processes have been studied by biological observations on each of the Labrador Sea occupations.

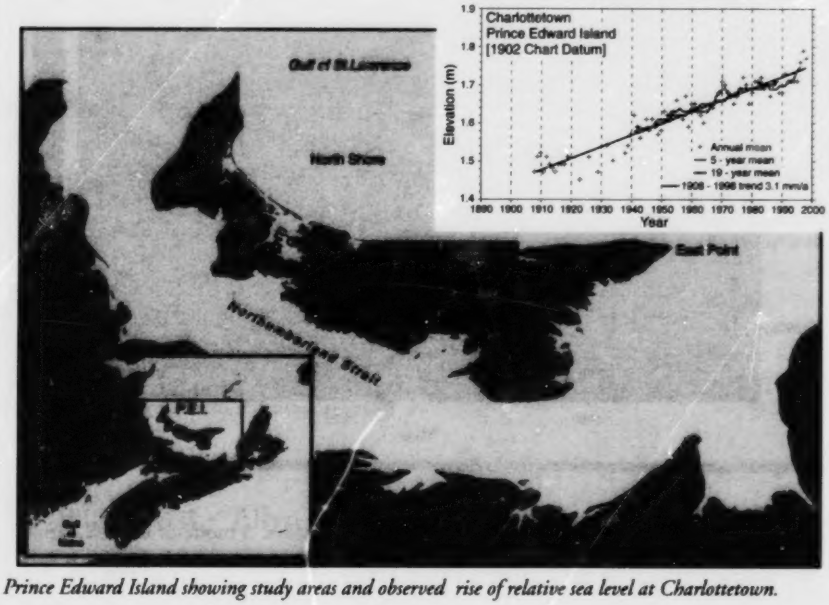
From 1990 through to 1994, the Labrador Sea experienced severe winter cooling. As a result, the waters which normally fill the upper 2 km of the Labrador Sea, deepened to more than 2.5 km. By 1994, these waters were colder and denser than had ever been observed. Since 1994, the winters have been less severe and winter convection has weakened. As a result, these waters of the Labrador Sea have become warmer, saltier and less dense. However, the remnants of the cold dense waters formed during the winter of 1993/94 can still be seen as a deep salinity minimum in the spring of 2000.

Climate science is collaborative and multidisciplinary. BIO's strong continuing programs in the Labrador Sea and the Atlantic Canadian shelves, have been the key for many successful collaborations with scientists from universities and research institutions in Canada, the US, Germany and Russia. Their scientific results play important roles in the planning of international climate programs such as the Climate Variability and Prediction program (CLIVAR).

Coastal Impacts of Climate Change in Prince Edward Island

Donald L. Forbes (Geological Survey of Canada [NRCan]), **Martha McCulloch** (Meteorological Service of Canada [EC]), **Richard Chagnon** (Canadian Ice Service [EC]), **Kelly MacDonald** (Environment Canada Corporate Affairs [EC]), **Gavin Manson** (Geological Survey of Canada [NRCan]), **Charles O'Reilly** (Canadian Hydrographic Service [DFO]), **George Parkes** (Meteorological Service of Canada [EC]), and **Keith Thompson** (Dalhousie University [Oceanography])

This multidisciplinary study of climate-change impacts on the coast of Prince Edward Island focuses on two contrasting coastal settings – the City of Charlottetown and the central North Shore. They were chosen to represent the major environmental issues involving sea-level rise, storm-surge flooding, changes in sea ice and coastal erosion in a mix of rural and urban socioeconomic contexts. The choice of project area was influenced by results of a national coastal sensitivity assessment (Shaw et al., 1998), which identified parts of the PEI coast as among the most vulnerable in Canada. This project, supported by the Climate Change Action Fund (CCAF), aims to identify critical coastal impacts associated with climate warming and sea-level rise, to develop a template for coastal impact assessments in other parts of the country, and to identify appropriate adaptation strategies for coastal communities.



Prince Edward Island showing study areas and observed rise of relative sea level at Charlottetown.

The coast of PEI is highly indented, the result of long-term relative sea-level rise causing back-flooding of river valleys to form elongate estuaries. Charlottetown is located on a sheltered harbour forming the confluence of two such flooded valleys. The North Shore consists of low sandstone headlands and sandy beaches with dunes; some of the beaches form barriers protecting large estuarine embayments, connected to the sea through tidal inlets of varying stability. Multibeam bathymetry and marine geological data demonstrate that former valleys extending seaward across the inner shelf contain estuarine sediments deposited 3-5 km seaward of the present coast, 20 m below present sea level, approximately 6000 years ago. With typical estuarine depths of less than 5 m, this implies a long-term mean rate of relative sea-level rise between 2.4 and 3.4 mm/year (~0.3 m/century). The mean rate of rise in relative sea level at Charlottetown this century, based on tide-gauge records going back to 1908, is 3.1 mm/year, slightly higher than the most probable long-term rate. The geological data also imply long-term retreat of the coast at rates averaging at least 0.5 m/year.

Other work undertaken in this project includes climatological analyses of wind, waves, sea ice, and water levels. The objective is to identify major storm events and years of reduced sea-ice duration or extent when winter storms may have been more damaging. Partners from Dalhousie University have applied a regional storm-surge model to observed events in the study area and are carrying out a statistical analysis of flooding potential under scenarios of accelerated sea-level rise and increased storminess. Airborne laser altimeter data are being used to develop flood hazard maps for events of specified probability under climate change. New urgency was recognized for this task following a major storm in January 2000, which caused record flooding at Charlottetown, up to 0.4 m above the previous observed high water, as well as at other locations in Northumberland Strait. Also as part of this project, the Canadian Hydrographic Service has undertaken differential Global Positioning System (DGPS) surveys to establish a common datum for water levels in the southern Gulf of St Lawrence, while GSC personnel carried out real-time kinematic DGPS surveys to measure observed water levels from the January storm and expand the network of shoreline erosion monitoring in northern Prince Edward Island. These surveys, combined with photogrammetric analysis of historical air photographs dating from 1935 to the present, provide data on erosion rates, with observed retreat as high as 3 m/year through the 1980s in an area where holiday homes have been lost to the sea. Another component of the project uses observed erosion rates and coastal geomorphology to develop an erosion hazard map for the North Shore as a basis for improved planning and zoning regulations under climate change.

An important part of this project to be carried out by Environment Canada involves an economic analysis of climate-change impacts, both in the urban area of Charlottetown (largely related to flooding risk) and on a representative part of the North Shore (related primarily to coastal erosion). The latter will use observed erosion rates and potential increases in erosion combined with assessed property values as one measure of the economic impact. In Charlottetown, an earlier study (Lane & Associates, 1988) identified many important properties and components of infrastructure that would be seriously affected by a 1 m rise in sea level, including harbour facilities, the harbourside complex, convention centre, other downtown properties, the storm sewer system, two pumping stations, and a sewage treatment plant. This project will refine the limits of potential flooding and associated impacts, recognizing that Charlottetown has experienced a rise of 0.3 m in mean sea level since 1900 and may face a rise of ~0.7 m by 2100, assuming 0.2 m/century crustal subsidence and 0.5 m/century global sea-level rise (the 'best estimate' of the Intergovernmental Panel on Climate Change). The physical and economic impacts identified in this project will be communicated to stakeholders through collaboration with the Federation of Canadian Municipalities. In this connection, possible adaptation measures will be identified, including such things as hazard mapping, public education, improved and expanded forecasting capacity, coastal protection (where feasible and cost-effective), accommodating impacts (e.g. modification of infrastructure), retreat from risk (e.g. amendment of zoning bylaws and setback requirements), and enhanced natural resilience (e.g. protection of coastal dune buffers).

References

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Precise Geoid Determination for Geo-Referencing and Oceanography

GEOIDE (Geomatics for Informed Decisions) Project No. 10

Michael G. Sideris (Dept. of Geomatics Engineering, University of Calgary), **Keith R. Thompson** (Dept. of Oceanography, Dalhousie University), **Petr Vaníček** (Dept. of Geodesy and Geomatics Engineering, University of New Brunswick), **Spiros Pagiatakis** (Geodetic Survey Division, Geomatics Canada, [NRCan]), **Charles O'Reilly** (Tides, Currents and Water Levels, Canadian Hydrographic Service [DFO]), and **Ross Hendry** (Ocean Sciences Division [DFO]).

GEOIDE – Geomatics for Informed Decisions - is a $30 million (1999-2002) Research and Development (R&D) investment program currently consolidating Canadian expertise in geomatics. As a federally supported Network of Centres of Excellence, GEOIDE brings together many of Canada's leading experts from 24 universities, 27 companies and 17 government agencies and departments. It selects and manages opportunity-driven R&D projects through a collaborative R&D investment program. An "institute without walls", GEOIDE funds projects with strong potential for fostering economic and social development in a networking environment. It is a strategic link to research funding and a critical mass of world-class expertise in the important arena of geomatics.

A GEOIDE research partnership consisting of Geomatics Canada, University of New Brunswick, University of Calgary, Dalhousie University and the Department of Fisheries and Oceans has undertaken a major refinement of the definition of the Canadian geoid. Three separate geoid models are being prepared by the University of New Brunswick, the University of Calgary and

Geomatics Canada during 1999/00, all due for completion by December 2000. Geomatics Canada will adjudicate the final results and announce the official revised Canadian model.

Background and Statement of Problems

The geoid is the equipotential surface of the Earth's gravity field best approximating the mean sea level. Such a reference surface is needed for a number of modern mapping, oceanographic and geophysical applications. Required absolute accuracies are as high as 1 cm or better for oceanography. Required relative accuracies are as high as 0.5 ppm (parts per million of the interstation distance) or better for geodynamics, precise engineering surveys, monitoring of Arctic ice caps, and very precise leveling by the Global Positioning System (GPS). Current geoid prediction methods do not generally meet these high accuracy requirements; being typically of the order of a few decimetres absolute and 2 ppm relative, especially over mountainous regions. This poor performance is due to insufficient density and accuracy of the data and approximations employed in various computational methods and data reduction models.

The geoid is computed by a combination of geopotential model coefficients, gravity anomalies, and heights/depths/densities in an effort to properly model its long, medium and short wavelengths, respectively. In oceanic regions, the geoid can also be computed from satellite altimetry, which provides sea surface heights (SSHs) above a reference ellipsoid. Extensive data pre-processing is necessary, requiring cooperation of geodesists and oceanographers. Firstly, the sea-surface topography (SST) must be computed and subtracted from the SSHs in order to get geoid heights. SST can be modeled using oceanographic data or can be derived as an extra unknown in the geoid solution. Secondly, several corrections must be applied to the altimeter ranges for the effects of orbital and instrumental errors, propagation through the atmosphere, tides and the state of the sea surface.

Traditionally, marine gravity measurements have been used alone to predict an oceanic geoid while altimetry-derived undulations have been inverted, either directly or by first deriving deflections, to determine gravity over oceans. Shipborne gravity measurements give slightly better resolution than altimetry measurements but their spatial coverage is limited. Consequently, altimeter data from many missions should be combined for extended coverage and comparable resolution. Given the huge amounts of satellite data with different error characteristics, it is apparent that there is a need for extremely fast spectral processing methods that could take data noise into account. In addition, the problems of effectively combining data and modeling oceanographic phenomena in coastal regions need to be investigated.

To reach cm-level accuracies for the geoid and to further improve the data handling and the efficiency of the geoid computation methods, both theoretical and practical refinements are necessary. An estimated time of four years will be required. The objectives, and the corresponding methodology and deliverables for each year of research, are outlined here:

Objective 1. Refinement of gravimetric geoid prediction methods.

Objective 2. Investigation of the required data coverage, accuracy, and resolution for cm-level geoid determination.

Objective 3. Investigation of geoid, gravity, and SST determination methods using satellite altimetry and shipborne gravimetry data in the oceans.

Objective 4. Solution of the altimetry-gravimetry problem in coastal regions and incorporation of other available data sets in precise geoid determination.

As part of this research initiative, Dalhousie University has developed a high-resolution, prognostic model of the tidal circulation in the Gulf of St. Lawrence. The model has a spatial resolution of 2.5 km, which allows accurate simulation of many small-scale features evident in the observed circulation. Due to the presence of ice and lack of observations in winter, they have focused on the ice free seasons. The forcing fields, and hence the model output, represent the general climatology of the Gulf rather than that of a particular year. The purpose of this work is to use the tilts of mean sea level from the model to provide an independent check of the geoid by comparing them to the tilts of sea level derived from geodetically referenced tide gauges.

The CHS is providing significant support to this project by undertaking high precision GPS surveys of numerous tide gauge stations throughout Canada. All long-term Permanent Water Level Network (PWLN) stations have been surveyed as close as possible to centimeter precision. All short-term sites surveyed to date have GPS geodetic heights established to the WGS84 Ellipsoid with precision ranging from 0.004 to 0.086 centimeters (root mean square).

Deliverables will include a 3D spatial model of Mean Water Level for Year 2000. This model will define the mean level of the coastal ocean for several geodetic and hydrographic purposes. Temporally normalized to a specified year and tied to a temporally invariant reference surface, it will act as an accurate and absolute baseline for past, present and future sea level trends. This will address the growing confusion caused by periodic adjustments to vertical datums. These adjustments are required to align hydrographic charts to ambient sea levels and will increase with the anticipated acceleration of sea level due to climate change.

RESOURCE MANAGEMENT HIGHLIGHTS

Oceans and Coastal Management - Erin Rankin

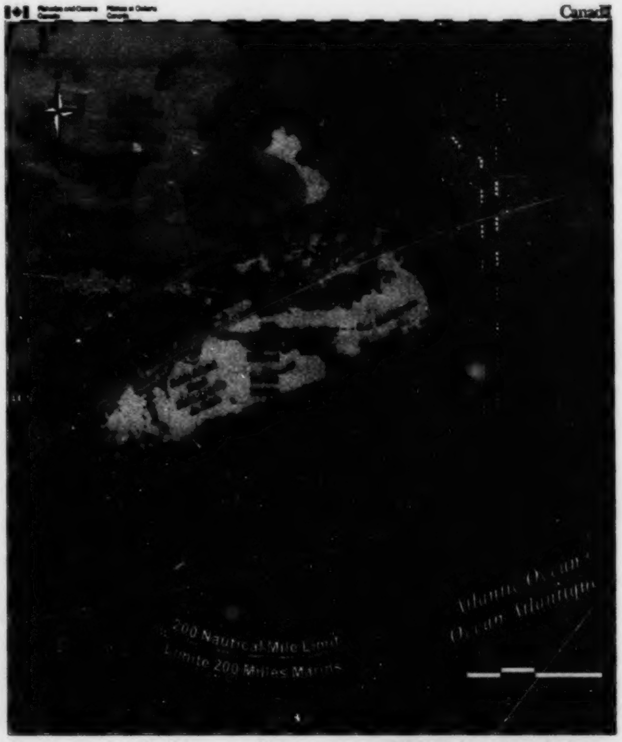
Established in 1997, the Oceans and Coastal Management Division (OCMD) is leading the Maritimes Region forward in the implementation of the 1997 *Oceans Act*. Previously managed on a sector by sector basis, DFO has been tasked with collaboratively managing use of ocean space and resources on the principles of integration, precaution and sustainable development.

Photo by M.I. Buzeta and M. Strong.

In meeting these principles, OCMD is working in four main program areas: integrated management, marine environmental quality, marine protected areas and oceans education. Underlying these programs will be the development of the Oceans Strategy and the Oceans and Coastal Management (OCM) Framework; together these documents serve as a common link for all program areas.

Photo by M.I. Buzeta and M. Strong.

Currently OCMD is addressing the call for integrated approaches by developing integrated management plans for the eastern Scotian Shelf, the Bras d'Or Lakes, the Bay of Fundy, and the Southern Gulf of St. Lawrence. Lead by OCMD, the Eastern Scotian Shelf Integrated Management (ESSIM) project is the largest project of its kind in Canada. Chosen for its high level of biological diversity and multiple ocean uses, OCMD staff will be working towards an integrated management plan through a collaborative process for this area.



Eastern Scotian Shelf Integrated Management (ESSIM) Area (map by Stan Johnston).

OCMD is also involved in partnerships to improve networking, information exchange and local coordination to get communities involved in integrated management. In the Bras d'Or Lakes, OCMD is partnering with several groups and institutions to develop a community-driven, web-based knowledge system called the Paqtatek Integrated Knowledge System (PIKS). Serving citizens, governments, aboriginal communities, private sector and non-government organizations, PIKS will help empower individuals and communities to take action. Similarly, in the Bay of Fundy OCMD is partnering with the Integrated Coastal Planning Project at Daltech, and the Atlantic Coastal Zone Information Steering Committee (ACZISC) in support of the Fundy Forum. The Fundy Forum is designed to increase networking among the groups and individuals around the bay by offering timed discussions and information on local projects and initiatives. OCMD is also working closely with the Southern Gulf of St. Lawrence Coalition on Sustainability which is a partnership of government, community and industry that uses a community-based approach to address key issues in the Southern Gulf of St. Lawrence.

The Marine Protected Areas (MPA) program is working to meet the DFO Oceans' responsibility in creating a national network of MPAs. As part of this national program, OCMD is focusing on several sites including the Sable Gully, Basin Head, and Musquash Estuary. To move the designation process forward in each of these sites, OCMD is working with scientists, community groups, and private sector interests to develop management proposals. As part of this program, a CD-ROM has been developed that takes users on a virtual tour of the Sable Gully. Released jointly by DFO and Environment Canada, the CD-ROM is an interactive tool relying on animations, video clips, sound bytes, biological descriptions, maps and graphics to introduce users to the physical and biological properties of this remarkable, natural phenomenon.

Another important program area is oceans education. OCMD has been working with the Nova Scotia Department of Education and Culture in creating a grade 11 science credit course entitled Oceans 11. Oceans 11 is designed to expose students to oceans science and familiarize them with important oceans issues. The development of this curriculum involved educators, government personnel, industry leaders and community-based groups to ensure that a broad base of perspectives was included. Oceans 11 is now being taught in high schools around Nova Scotia.

Habitat Management Division - Jim Ross

The Habitat Management Division administers those sections of the *Fisheries Act* aimed at preventing the alteration, disruption or destruction of fish habitat. Fish habitat can be defined as locations in our lakes, streams, rivers, wetlands, estuaries, and oceans on which fish depend to carry out their life processes. Spawning grounds, nursery and rearing areas, food supply, and migration routes are all examples of fish habitats.Habitat Management ensures that there is no net loss of fish habitat through implementation of its *Policy for the Management of Fish Habitat.* The policy's objective is to produce a net gain of the natural productive capacity of fish habitats for the nation's fisheries resources to benefit Canadians. This is accomplished through three goals: conservation, restoration, and development of fish habitat.

Under the goal of conservation, it is the responsibility of Habitat Management to conserve the current productive capacity of fish habitat of Canada's fisheries resources. Recent initiatives supporting this goal include:

Pipeline crossing with proper sediment and erosion control for the protection of fish habitat.

- Habitat Management conducted a workshop, in cooperation with the Halifax Regional Municipality, entitled: *Preserving the Environment of the Halifax Harbour.* The purpose of the workshop was to discuss regulatory overlaps, the potential for the integration of marine and freshwater resource management, and identification of conservation and restoration opportunities in the harbour.

- Annually, Habitat Management, in co-operation with the Nova Scotia Department of Transportation and Public Works, DalTech, and the Nova Scotia Department of the Environment, have conducted an *Erosion and Sediment Control Workshop* to promote environmental awareness. The focus is on environmental regulations and sediment and erosion controls associated with forestry operations, and highway, pipeline, and subdivision construction. Approximately 350 individuals have attended the course including engineers, pipeline and environmental inspectors, contractors, government regulators, fishery officers, and consultants.

Noel Lake, Hants County, N.S.

The second goal, fish habitat restoration, is achieved through the rehabilitation of the productive capacity of fish habitats. The third goal is fish habitat development which is accomplished by developing new or by improving existing habitat. Both restoration and development are usually undertaken in cooperation with community groups, resource use organizations, and other government agencies. Habitat Management at BIO is working with 26 community watershed groups involved directly in fish habitat restoration projects in Nova Scotia. We are also involved in assisting these groups in striving for a more holistic approach to watershed management. This is accomplished through public education and training in proper land-use management, the prevention of point and non-point pollution, and improvement of water quality.

Additional information may be obtained from our regional office at Bedford Institute of Oceanography (902) 426-1642, or visit our website at: www.bio.gc.ca

The Provision of Science to Our Clients - the Regional Advisory Process or RAP - Robert N. O'Boyle

The Department of Fisheries and Oceans (DFO) is responsible for the management of all the aquatic resources and their habitat off the coast of Canada. These waters are used by a vast array of Canadians – from clam diggers to oil riggers – to extract resources and earn a living. It is DFO's role to ensure that the resources are exploited wisely and are conserved for future generations of Canadians. In order to do this, DFO needs the best science it can obtain in order to judge the state of the resources and their marine habitat and advise on their best use. As part of this, the Regional Advisory Process (or RAP) was created to coordinate the provision of scientific advise to all of DFO's ocean clients. The Maritime Provinces RAP process serves both DFO's Maritimes and Gulf regions.

The fishing industry in the Maritimes, one of DFO's biggest clients, harvests just over 100 fish and invertebrate populations or stocks – from cod, haddock and yellowtail on Georges Bank in the south to snow crab, lobster and shrimp off Cape Breton in the north. Information on the size of each one of these stocks is required, as well as an estimate of its productive potential. Scientists at BIO conduct surveys each year on these resources to determine their size and productivity, as well as collect information on their growth, feeding, maturity, and mortality. Information is also collected from the fishing industry – the catch rates that fishermen experience, the size composition of the caught fish, and other biological information. Most importantly, DFO and the fishing industry are collaborating on a number of joint surveys that are used to supplement the DFO surveys. All this information is used in a process called stock assessment to determine the state of the stocks and their productivity.

Given the impact that assessments can have on the fishing industry, it is important to ensure that the assessments are of high and consistent quality. RAP therefore coordinates the review of these assessments. Here's how it works. The RAP Coordination Committee, which consists of DFO managers and is chaired by the RAP Coordinator, decides what stocks are assessed and when. For instance, stock status reports must be available to DFO fisheries managers before they prepare the annual fisheries management plans. RAP meetings are scheduled accordingly and can last one to five days, depending on the number of stocks being assessed. For each meeting, the RAP Coordinator, in consultation with the appropriate scientists and fishery managers, outlines a set of questions and issues to be addressed in each assessment. A team of scientists then undertakes the analyses for the assessment and produces a working paper which is discussed and peer reviewed at a RAP meeting. This meeting is chaired by an individual appointed by the RAP Coordinator. He or she is responsible for ensuring that the meeting has the attendees with the expertise necessary to review the assessment. Therefore, not only are scientific experts from BIO invited to attend but also experts from other regions and sometimes other countries. Members of the fishing industry are specifically invited to provide their input on observations in the fishery. This has proven particularly effective in resolving differences when the scientific and fishery observations are seemingly in conflict. As well, since there are a number of joint industry/DFO surveys underway, it is important to have participation of industry when the results of these surveys are discussed.

DFO has a number of clients outside the fishing industry. These include the oil and gas industry, the transportation sector and marine mining interests. The impact of these human activities on the marine habitat is also being assessed through the RAP, in a process analogous to that used for stock assessments. While stock assessments take place routinely and take two to three months, habitat evaluations can take up to six months. They are not assessed on a regular schedule. Some recent examples of RAP habitat reviews include the effects of land use practices on fish, shellfish, and their habitats on Prince Edward Island and the effects of acid rain on the Atlantic salmon of the Southern Upland of Nova Scotia.

There are three main reports produced by the RAP process. First, the meeting chair prepares a Proceedings which outlines who was at the meeting, issues addressed, comments made, and research recommendations. Second, the science team prepares a Research Document, which provides all the technical details of the analyses presented and discussed at the RAP meeting. Finally, the bottom line for each assessment, be it stock or habitat, is provided in a summary report – Stock Status Report for fish stock assessments and Habitat Status Report for habitat issues. There is also a Fisheries Status Report series which is used to document the results of the evaluations of fishery regulations. These reports are all made available to the appropriate DFO managers soon after a RAP meeting, who then use them in their fishery and habitat management planning process. It is thus the main vehicle of communication with DFO clients on resource and habitat status and advice. All these RAP documents are publicly available on the RAP internet site at

http://www.mar.dfo-mpo.gc.ca/science/rap/internet/Home.htm

Besides these documents, this site provides background information on the structure and function of RAP and the meeting schedule.

What lies in the future for RAP? It is becoming increasingly evident that we have to start managing ocean usage in a broader, ecosystem, context. Canada is one of a few nations undertaking ecosystem-based management. The required science is complex and will require considerable effort on the part of scientists to make it a reality. RAP has a pivotal role in ensuring that the most appropriate science is brought to bear on ecosystem-based management and that DFO both gains from and contributes to research on ecosystems elsewhere in the world.

Environment Canada at BIO - Diane Tremblay

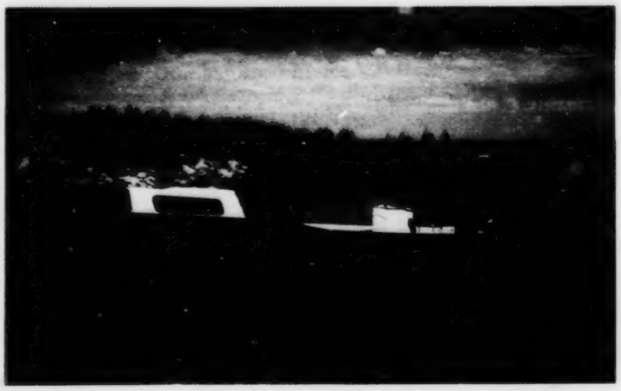
Staff of the Shellfish Section, Environmental Protection Branch - Atlantic Region, Environment Canada, are based at the Bedford Institute of Oceanography (BIO). The Shellfish Section conducts sanitary and water quality surveys to identify sources of fecal pollution and their impact on the Atlantic coastal waters.

The principal role of the Section's microbiology laboratory is to perform bacteriological analyses of water samples in support of the Canadian Shellfish Sanitation Program. This program is the result of a Canada/U.S. bilateral agreement signed in 1948 to improve sanitary practices in the shellfish industries of the two countries. The program is a shared responsibility of three departments: Environment Canada, Fisheries and Oceans and the Canadian Food Inspection Agency. Environment Canada is the lead agency for the water classification component of this program and classifies shellfish growing areas based on pollution sources and bacteriological water quality affecting these areas.

The field and laboratory component of the group operates from BIO. Along with the sanitary team, we are responsible for the classification of the Atlantic coastal waters for the harvesting of shellfish. Sampling for most of mainland Nova Scotia is carried out from this laboratory. Water samples are tested for fecal coliforms to determine if the area meets the standards set in the Canadian Shellfish Sanitation Program. In 2000, the BIO teams have surveyed areas in Nova Scotia from Pugwash to Havre Boucher; from Musquodoboit to Pubnico; and also Annapolis, Five Islands and Torbay. Samples are brought back, Monday through Thursday, during the sampling season for analysis within six hours. Results are available in 24 hours.

A classification based on the Canadian Shellfish Sanitation Program standard is determined for an area after analysis of at least 15 sets of data and a critical look at the sanitary conditions around the coastline. The recommended classifications are reviewed twice a year (in the spring and fall) by the Atlantic Shellfish Area Classification Committee. The committee is composed of members from Environment Canada, Fisheries and Oceans, the Canadian Food Inspection Agency and representatives from the provincial governments of Nova Scotia, New Brunswick, Prince Edward Island and Newfoundland. Closures are written as Department of Fisheries and Oceans prohibition orders and enforced by that department. Classified areas are re-surveyed every one to three years based on risk assessment. Many community groups have been involved in remediation work to help clean up the coastal environment. This has resulted in the opening of previously closed areas for shellfish harvesting.

For more information on the shellfish program and Environment Canada's Atlantic Region visit our website at: http://www.atl.ec.gc.ca



Water sampling – Eastern Shore of Nova Scotia.

TECHNICAL SUPPORT HIGHLIGHTS

BIO has a Presence on the Web: http://www.bio.gc.ca

Paul Boudreau and Joni Henderson

You can now find BIO on the web. A working group of staff representing all departments, developed a web page in the summer of 2000. The web site is a focal point for the general public and scientific community searching for information on the research programs and personnel at the Institute. The intention is to provide the world a window into marine science and information as it is created at BIO.

In addition to the usual challenge of finding the right balance between pictures and words, the web site development required consideration of the different activities and resources of resident departments at BIO, namely the Department of Fisheries and Oceans, Natural Resources Canada, Environment Canada, and the Department of National Defence.

The web page was posted in August 2000. It highlights the research and program activities undertaken at BIO in the fields of Marine Geoscience, Ocean Sciences, Marine Environmental Sciences, Biological Sciences, Hydrography, and Oceans and Habitat Management. The *Research/Programs* section contains a number of links to other web pages documenting BIO activities undertaken by resident departments.

Information contained in the site includes the publications and products generated by staff of BIO. For example, mariners can find information on the latest navigational charts in electronic or paper format and daily tide tables listed on an area basis. Under oceanography, information is found on a wide range of subjects including oceanographic observations and climatologies, remote sensing products, and ocean moorings. The link to GSC Atlantic provides extensive marine geoscience information on subjects such as geoscience surveys, research on mineral deposits, basin analyses and petroleum geology, marine environmental geology, and technology research and development. The schedules and activities of the five survey vessels that operate out of BIO can be found under *Ships*, and information on the extensive holdings of the DFO libraries across Canada under *Publications*.

The Bedford Institute of Oceanography.

Additionally, there is an *Education* link to assist students and educators wishing to explore the fields of marine geoscience, oceanography and biological science. The summer tour schedule is provided along with instructions on the location of BIO. Links are also available to some of the associated activities including the *Bedford Institute of Oceanography Oceans Association*, the *Huntsman Award*, and the *BIO Gift Shop*.

Staff are actively considering ways to update, improve and expand the existing work. As more web sites are posted by BIO staff, the links to web resources will grow. Feedback on what you liked and suggestions for improvements can be provided using the "Contact Us" feature.

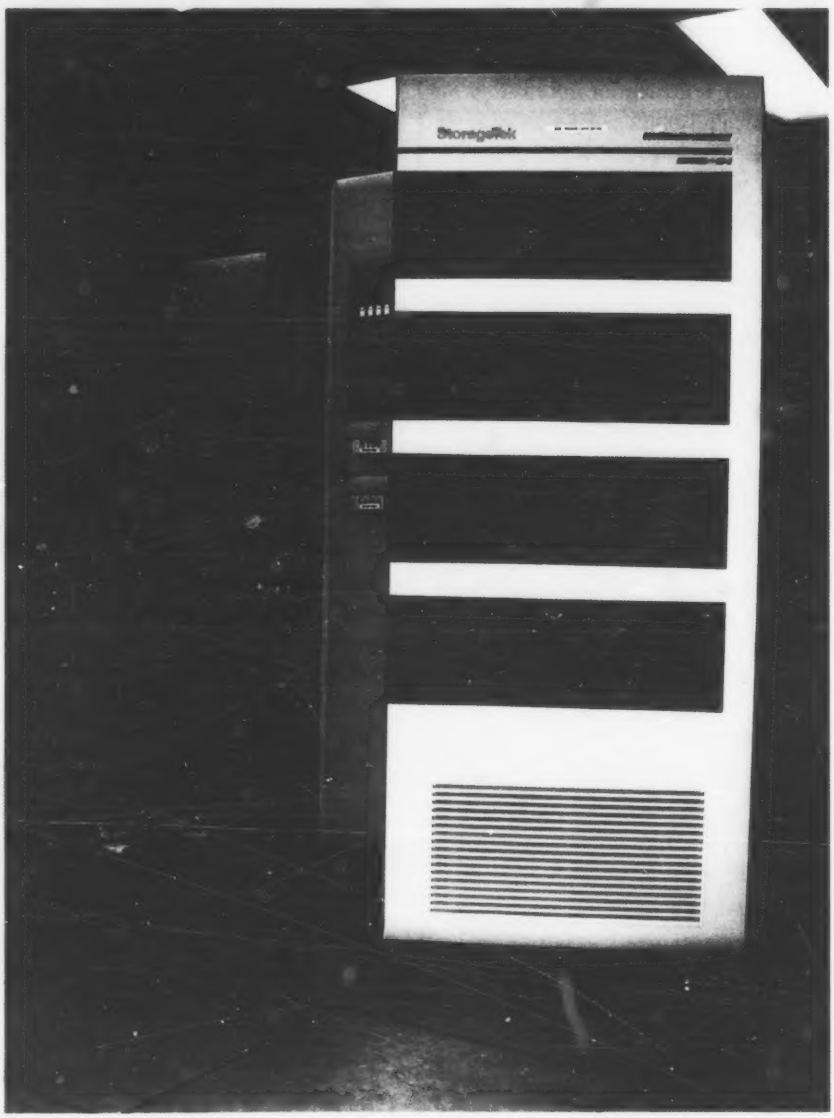
Informatics - Gary Collins

Informatics maintains and operates the Unix and NT applications servers used for scientific data processing, analysis and modelling. Increasingly, Science Branch data management is becoming Oracle based and a significant effort is expended in Oracle Database Administration to ensure optimal and error-free functioning of the database software, and data integrity, in a variety of operating systems/hardware environments.

A Network Attached Storage system provides a data management service that consists of backups and near-line, remotely mounted, directories to Science Branch servers at BIO. The attached storage is provided by a Mass Storage Management (MSM) system that consists of a Storagetek Wolfcreek robotic tape library that is managed by two Solaris servers. The Wolfcreek library houses four high-performance Redwood drives and can accommodate 500 tape cartridges for a capacity of 35 terabytes (1 terabytes = 1000 gigabytes). At present, approximately 40 servers are automatically backed up over the network by this system, using Veritas Netbackup software. In excess of 12 terabytes per month are streamed through the Redwood drives. The Mass Storage Management system also provides near-line storage to servers within BIO that migrate, under software control, infrequently used files to the less costly cartridges. One terabyte of disk and the Wolfcreek library provides this function. The migration of files between the two media is managed automatically by Veritas' Storage Migrator software based on file size and ageing characteristics. At present 3 terabytes of near-line data are available to BIO application servers.

Informatics also operates and maintains the networking infrastructure and the desktop workstation environment.

Informatics has worked hard in the previous year, under the umbrella of Y2K, to rewrite, remediate, and upgrade a number of Science applications. Major goals were then achieved in the year 2000; they were that many applications were rewritten to a common architecture standard and many were migrated to a Web based front end for easier use and greater dissemination of information both to DFO staff and the general public. DFO has a standard suite of tools from which to develop and maintain applications. Using these tools has resulted in Science having systems that are well documented, easy to maintain, and are more readily able to be used in conjunction with each other. The Science applications of today are built on Oracle databases which house the data, object-oriented code which performs the data validation and analysis, and client-server and Web based user interfaces which are used for performing data entry and query processing. The ability exists today, as it never has before, to link data and information from many different sources.



Wolfcreek robotic tape library.

Knowledge and Information Management at GSC Atlantic

Mark Williamson and Phil Moir

The transformation to a connected, on-line public service involves many technological and human resource challenges. Although such transformations are rarely completed without morphing into further transformations, the associated incremental changes are fundamentally altering the fabric of government and the nature of governance itself. The way public servants see their roles, conduct their business and the way they are viewed by the clients they serve reflect just a few of the changes underway.

- How will these changes influence how the GSC Atlantic conducts its business?
- What can/should GSC Atlantic do to maximize contributions to these developments?
- What opportunities do they present for more effective and efficient performance and delivery of the science program.

Answers to these and other questions are not straightforward. What is clear, however, is that government science and technology organizations like GSC Atlantic, are on the leading edge when it comes to generating the new data, information and knowledge necessary to bring meaning to the term "connected Canadians". This note provides a snapshot of some current GSC Atlantic initiatives that set out to digitally gather/archive marine geoscience knowledge and information.

Current "Access" initiatives at GSCA:

BASIN
what: The BASIN database contains a wealth of geological, geophysical and engineering information related to many years of petroleum exploration, primarily offshore eastern Canada. The web site provides access to most of the database.
why: One stop access for data retrieval and a well organized, single location for data archiving.
who for: GSC, provincial governments, regulatory agencies, petroleum industry, and universities.
view at: http:\\agc.bio.ns.ca\BASIN

C-Margin
what: Canadian MARine Geoscience Information Network. Meta database and smart theme base web searching.The continuing objective of this project is to build a smart, web-enabled interface to geoscience information for marine and coastal areas of Canada.
why: Maximize the accessibility and utility of geoscience information in Canada's marine areas for decision making.
who for: Governments, industry, regulatory agencies, and researchers.
view at: http://margin.bio.ns.ca/CMARGIN

Coastweb
what: Geological Survey of Canada web site on the geology and physical processes of Canada's coastline.
who for: Governments, industry, regulatory agencies, researchers, and coastal land owners.
view at: http://agc.bio.ns.ca/COASTWEB

Earthnet
what: EarthNet is a virtual resource centre of earth science resource information and contacts.
why: Outreach to educators and students.
who for: Teachers, home educators and elementary, junior high and senior students.
view at: http://agc.bio.ns.ca/EarthNet

Geocollections
what: The GeoCollections web site provides comprehensive information about geoscience collections, including archive location, access procedures and contacts.
why: Improve accessibility to and awareness of collections. The Canadian geoscience community, including the GSC, has long collected and archived geoscience materials in support of basic research. Much of these materials are accessible to the public.
who for: Governments, industry, and university researchers.
view at: http://agc.bio.ns.ca/GEOCOL

ED
what: The Expedition Database (ED) contains data related to the scientific cruises conducted by the GSC as well as the 'Stations' and Seismic surveys associated with each individual cruise or in a given area.
why: One stop access for data retrieval and well organized location for archiving data from expeditions and related research.
who for: Governments, industry, and university.
view at: http://agc.bio.ns.ca/ED

These and similar initiatives are planned, prioritized and implemented through a two-step process. Step one involves a three-way dialog between GSC Atlantic management, representatives of the GSC Atlantic science and support user community, and in-house information technology professionals working on a day to day basis on data/information system infrastructure. The needs and priorities established by this group reflect the needs of our staff and the broader government and non-government client base for rapid and comprehensive access to our data, information and knowledge. Step two involves an implemetation team tasked to accomplish recognised priorities and goals. Members of this team oversee web content and development, internal and external links to government and non-government initiatives and emerging standards, data and information systems development, and GIS applications. One key initial task has been the construction of a systematic electronic inventory of all data and information GSC Atlantic has generated throughout its three decades of existence. This forms the backbone of a system that will provide instant access to information on where GSC Atlantic has conducted its science operations, what data has been collected, location of the data (and in some cases access to that data), what has been done to the data, as well as the myriad of map and other interpretive products originating from the data.

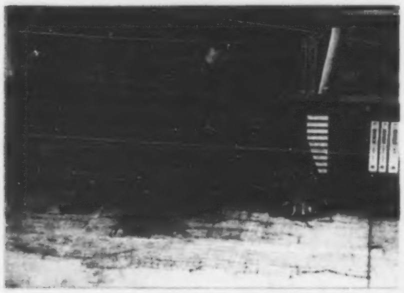
GSC Atlantic's efforts are interlinked with national efforts and should be viewed within the framework of NRCan's Earth Science Sector, GeoConnections, Canadian Geoscience Knowledge Network (CGKN) and Government on Line (GOL) initiatives. GSC Atlantic staff are involved in the development of a national information management infrastructure as well as adopting and implementing standards, systems, and methodologies.

Bedford Institute of Oceanography (BIO) - Archives

Anna Fiander

The Bedford Institute of Oceanography Archives was initiated in an effort to preserve the corporate memory of the Institute. Since its inception in 1998, the BIO Archives has gained momentum and interest to become a substantial collection of material focusing on BIO and its place as a community leader in marine affairs.

The BIO Archives contains a collection of historical documents and is collecting photographic records of BIO, memorabilia, and prototype equipment developed at the Institute.



Lois Loewen looking through the original blueprints for CSS Hudson.

The paper documentation is protected in fifty acid-free storage boxes, housed in a secure area. Plans are underway to have a designated space for the Archives, with room to display and examine items for research. This documentation is divided into twelve broad categories:

- Internal Publications
- Personal Papers
- Oceanography in Canada (General History)
- Historical Information
- Organization
- Operations
- Ships and Cruises
- Old Ocean Records
- William Bell Dawson Papers
- Special Projects
- Library Records
- Newspaper Clippings

Mike Gorvett with some of the prototype equipment of the Archives.

The BIO Archives contains a paper record of the history of the Institute, from the planning stages in the late 1950s, to the selection of the location for the Institute on the rocky shores of Bedford Basin. The various stages of construction are well documented through black & white photographs. Copies of the Official Opening Ceremonies held in 1962 are included, as well as documentation on the speeches given by visiting dignitaries.

GSC Atlantic Technical Support Group

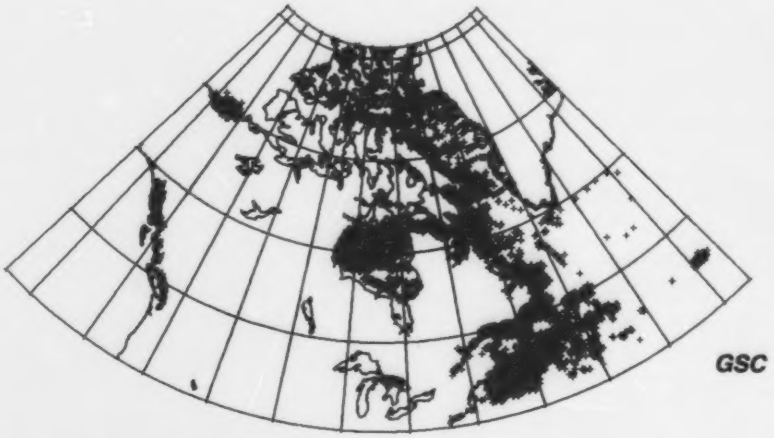
The Technical Support group of the Geological Survey of Canada (Atlantic) supports program delivery by operating and maintaining a comprehensive inventory of field equipment for use by researchers, developing new equipment and instruments, and mobilizing and demobilizing survey vessels. Field programs are conducted in coastal and offshore regions of Eastern Canada and the Arctic - stretching from the Gulf of Maine to the Beaufort Sea, and including the Great Lakes. Below is a list of some of the equipment maintained by the group:

- surveying and mapping systems
- side scan sonar
- sub-bottom profilers
- digital data recording systems
- single and multi-channel reflection profilers
- sleeve guns
- aerial video cameras
- coring systems, grab samplers and dredges

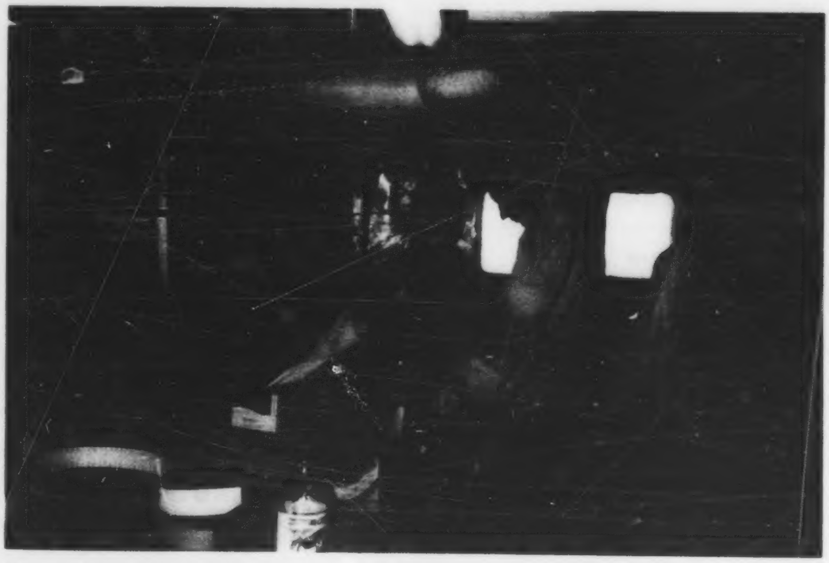
The 2000 field season was especially busy, with several shipborne programs run concurrently. In addition to the regular scientific program, collaborative research programs with industry triggered four separate cruises on the Scotian continental slope. Two private sector ships, equipped with multibeam swath sounder systems, were contracted to survey approximately 25,000 km^2 of seabed, representing the largest survey of its kind to date in Canada. Habitat mapping, in collaboration with CHS and the Offshore Scallop Producers Group, resulted in several surveys of the offshore banks in southern Nova Scotia.

Curation Activities at GSC Atlantic - Iris Hardy

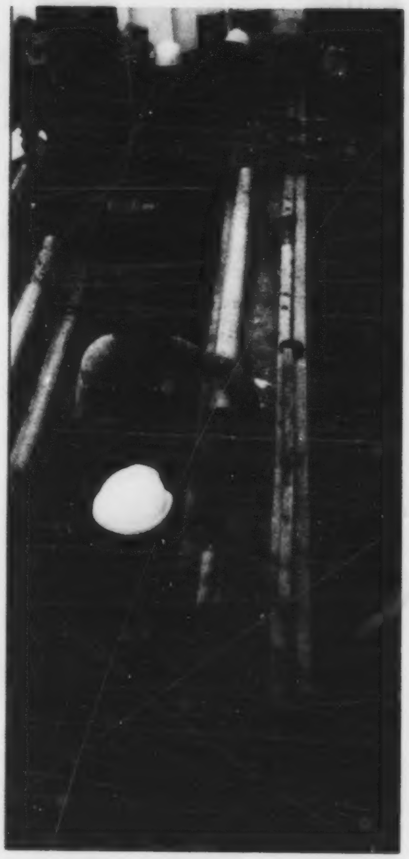
The Geological Survey of Canada (Atlantic) maintains an extensive collection of unconsolidated marine sedimentary cores, associated processed sample residues, and geophysical data recovered during more than 900 onshore and offshore field programs since the 1970s. These holdings represent the National Marine Geoscience Collection, which is maintained to provide baseline information for future collection and research by the national and international geoscientific community. The material is conserved within a secure, modern 10,000 ft^2 repository located at the Bedford Institute of Oceanography. Each year, GSC Atlantic acquires additional samples and records to support ongoing research programs. To date, there are more than 14,000 cores of soft marine sediment and 30,000 lineal metres of paper records or analog data. This collection represents a 1.6 million mile^2 offshore area and a coastal coverage of 11,129 nautical miles, stretching from the Canada/US border in the Gulf of Maine to marine areas in the Arctic Archipelago, Arctic Ocean and Beaufort Sea. Access to these collections can be provided by pre-arranged tours or by visiting us at our website: http://agcwww.bio.ns.ca/GEOCOL.



Extent of sampling and geophysical holdings.



Processing cores onboard ship.



Acquisition of core onboard ship.

Marine sedimentary cores constitute the bulk of the National Marine Geoscience Collection. Processing of most cores is conducted onboard ship, or later in the state-of-the-art, general purpose Core Laboratory at BIO. Core analyses may include split core measurements for visual core description, colour reflectance/spectra using a spectrophotometer, photography, whole core x-ray, x-ray fluorescence, magnetic susceptibility, acoustic compressional wave velocity and gamma ray attenuation. Cores are preserved in a temperature-controlled facility at 4°C for at least seven years. All samples and their associated data are available to the geoscientific community. GSC Atlantic strongly supports the use and maintenance of these holdings. Routine requests for access to this extensive geoscientific collection, are made by universities and industry worldwide, to complement their ongoing research.

Outreach at BIO (Natural Resources Canada and Fisheries and Oceans Canada) - Jennifer L. Bates, Rob Fensome, Joni Henderson, John Shimeld, and Graham Williams

Staff at the Bedford Institute of Oceanography recognize a need to promote science within the community. Many individuals give presentations at schools and libraries, help with science fairs or community events, and assist with job shadowing or the "take your kids to work" initiatives. More structured programs at BIO include: the annual EdGEO workshops (this is a national program), the Oceans 11 science course, participation in the Cooperative Education Program, BIO Career Day, tours of the Institute, and education web site development.

Since 1994, several geoscientists at the Geological Survey of Canada (GSC) Atlantic, a division of Natural Resources Canada, along with their partner volunteers at the Nova Scotia Department of Natural Resources, the Nova Scotia Museum of Natural History, Dal-Tech, and the Halifax Regional School Board, have been touring Nova Scotia conducting workshops for science teachers. The response from the teachers has been overwhelming and the workshops are annually "sold out" months prior to the late summer event. A web site (http://agc.bio.ns.ca/schools/edgeo/edgeo.html) contains additional information on the workshop program. In future, the program could grow to include a multi-disciplinary workshop focusing on the importance of earth science in our everyday lives.

Work on the Oceans 11 science course, developed by DFO and the Provincial Department of Education, continues. A workshop for Oceans 11 teachers was held at BIO in October 2000 and included a ship tour of Halifax Harbour with in-house experts providing commentary, talks, and hands-on activities.

Teachers' field trip.

EdGEO workshop.

Throughout the school year, staff at DFO participated in the Province's Co-operative Education Program, a program offered by school boards in Nova Scotia. This program integrates the school curriculum with the work environment and provides an educationally beneficial experience for students. The students competed to spend time at BIO working on proposals developed by staff and learned a great deal about the work conducted at a research establishment. In addition, the employees/supervisors received some very welcome assistance.

BIO staff hosted "Career Day" for high school students. To offer a meaningful experience to students, ten students were selected to participate from each of the high schools within the jurisdiction of the Halifax Regional School Board. Students viewed many displays that portrayed the wide range of careers available in the field of oceanography and related sciences. Employees were available to speak with the students about their careers, educational background, experience, and to answer questions. "Career Day" is expected be an annual event.

GSC Atlantic staff are among the many scientists and educators across Canada actively involved in the development of the web site EarthNet (http://agc.bio.ns.ca/EarthNet). Although the target audience is Canadian earth science educators, the many contributors seek to make the site a "virtual resource centre" for anyone interested in earth science - particularly Canadian earth science. The primary objective is to provide an environment for free access to Canadian information available from federal and provincial departments, museums and science centres, agencies and societies, and the private sector.

Summer tours of BIO were offered for the ninth consecutive year. Due to the increase in popularity of the tours, a second tour guide was required in 2000. Many staff provided information, materials, and answered questions from the guides so that they could tailor tours to meet clients needs. A number of changes were made throughout BIO to improve the visitors' tour. The mini-theatres were refurbished with new displays and videos; a demonstration fume hood with organic chemistry instrumentation was installed; improvements were made to the Fish Lab aquarium; the auditorium was equipped with a new sound system; a mural of Sable Island was painted adjacent to the library by Crissy Nickerson, a student at the Nova Scotia College of Art and Design; and an underwater environment was created in the area around the Fish Lab aquarium by local artist, Jenni Blackmore.

The Gift Shop, which opened this past year to promote awareness of BIO, was a popular stop for many visitors wishing to purchase mementoes of their visit to BIO. In keeping with the community spirit, revenue from this non-profit venture is donated to local charities.

The first modern book on the geological history of the Maritimes written for the general reader will be published in 2001. Un-

Career Day.

der the umbrella of the Atlantic Geoscience Society, the project was conceived, managed and edited by GSC Atlantic geoscientists. The book, entitled "The Last Billion Years" will contain an abundance of full colour paintings, photographs and graphics, many of which have been especially commissioned. The book will be relatively inexpensive thanks to grants and donations from industry, universities and the public sector, and so will make the geological story of the three provinces and the adjacent continental margin accessible to the public.

DND Route Survey - Jim Bradford

The navy maintains a section of ten personnel at BIO who are a part of a unit called TRINITY, which is Maritime Forces Atlantic's Joint Ocean Surveillance and Information Center. The Route Survey Office provides detailed ocean bottom data to the navy in support of seabed surveillance and intervention operations. A library of sidescan mapping of areas of naval interest is maintained together with a listing of seafloor objects that could influence the conduct of operations. As much as possible data are shared with other government agencies and survey activities are coordinated to reduce redundant activity. The primary data acquisition tool of the Route Survey Section is the multibeam sidescan sonar. These sonars are operated in continental shelf depths from the Navy's KINGSTON Class Coastal Defence Vessels and other platforms of opportunity. The AN/SQS 511 Multibeam Sidescan Sonar was purpose built for deployment from the KINGSTON Class and acquires high quality acoustic imagery at ten knots. In addition, the navy operates Klein 5000 Multibeam Sidescan Sonars for use in shallow waters and for rapid deployment activities. Close liaison is maintained with the Navy's Fleet Diving unit which provides ground truthing capability through divers and Remotely Operated Vehicles (ROVs).

AN SQS 511 Sonar being deployed from HMCS Glace Bay.

High Resolution Multibeam Sidescan Imagery of a shipwreck.

DFO Technical Services

The Technical Services directorate of the Coast Guard was created in 1994 to bring together the engineering and maintenance activities required by DFO relating to electronic, marine, and mechanical systems. The directorate is a client-focused service organization that brings this expertise together to support the operations of the Coast Guard, Science, and Fisheries Management sectors. Services include engineering, installation and maintenance of electronic systems used in support of marine and enforcement communications, navigational aids and science programs. The Oceanographic Systems Development unit, the Equipment and Systems Maintenance Division, and a section of Vessel Support Services are all located at the Bedford Institute of Oceanography while the Technical Services Directorate is located in Marine House, Dartmouth, NS.

The Oceanographic Systems Development unit creates original electronic and mechanical engineering designs, and provides technical support for the science and survey programs of DFO. The primary focus is on the development and integration of systems to meet the specialized needs of oceanographic researchers. Services include the design, development, integration, installation, and field testing of prototype systems, and providing specialized advice to clients and management. The Technical Graphics unit offers a range of graphic arts and photo-based services to support publications, displays, multi-media presentations, still photography, and videos for the scientific community and clients region wide. A high level of expertise has been developed in underwater still and video photography.

There is a major service center of the Equipment and Systems Maintenance Division that delivers professional electronic, electrical, and mechanical support to the programs. Technical staff repair and maintain electronic equipment and computer systems on the ships, hydrographic instrumentation, and scientific electronic equipment. They sail on critical voyages to render on-site technical maintenance support to the ship and the programs. Technical support to Science and Hydrography is provided through mobilization of survey launches, maintenance of the shallow water bottom mapping sonars, as well as the ocean mapping sonar and related instrumentation. This group is implementing a new national maintenance information system to improve effectiveness in tracking expenses and equipment performance in support of their clients.

The Small Vessel section of Vessel Support maintains and services the small crafts, portable labs, and a variety of shipborn scientific equipment. An on site carpenter's shop is provided to meet the needs of the science community, provide small craft repair services, and to support the large fleet vessels. The diesel shop services and maintains the various fast rescue craft and hydrographic survey launches used by both the fleet and the science community. Vessel Support at BIO provides the services of heavy material handling equipment and a number of electro-hydraulic winches and power units. A small fleet of road transport trailers are maintained which are used to move the various small fast rescue crafts when they are deployed to remote locations.

While the work of Technical Services contributes to all programs at BIO, they are of particular value to the Coast Guard Fleet, Science and the Canadian Hydrographic Service.

Charity at Bedford Institute of Oceanography

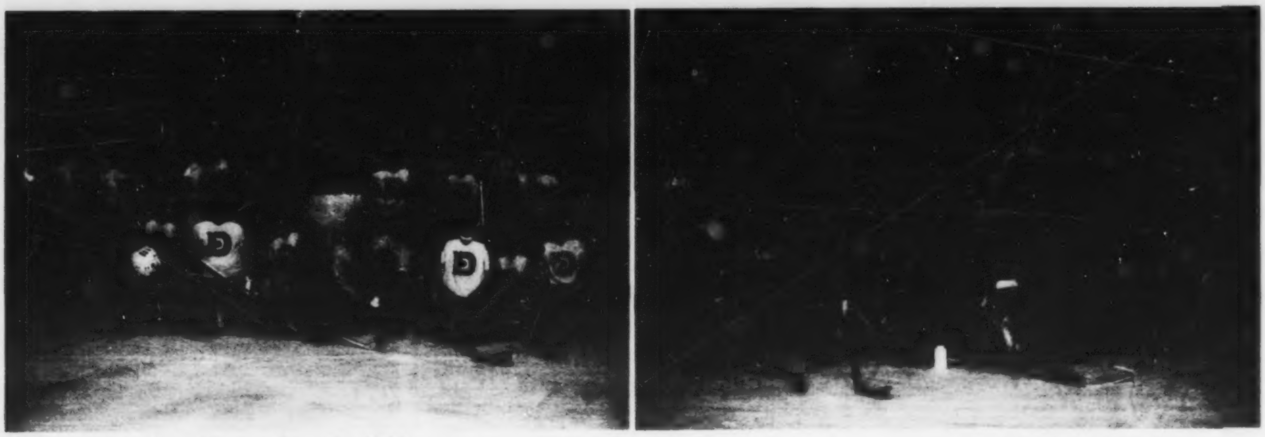
Shelley Armsworthy

Staff and retirees of the Bedford Institute of Oceanography participate annually in numerous charitable events. The largest charitable movement is the Government of Canada Workplace Charitable Campaign (GCWCC) that involves United Way/ Centraide, Health Partners, and numerous other registered charities across Canada.

The total BIO contribution from the Government of Canada Workplace Charitable Campaign for 2000 was $65,000, exceeding our goal of $50,000 by 30%! This was the most raised to date, and was exceptional considering that the campaign began at the end of September, a much later start than in previous years. In addition to gifts from staff and retirees, the proceeds of many interesting and entertaining special events are organized and hosted by volunteering staff. In 2000, these events included a book sale, two bake sales, a BBQ, a staff hockey game, family skate, and Christmas Party, monthly 50/50 draws, and the new and popular draw for a day off of work.

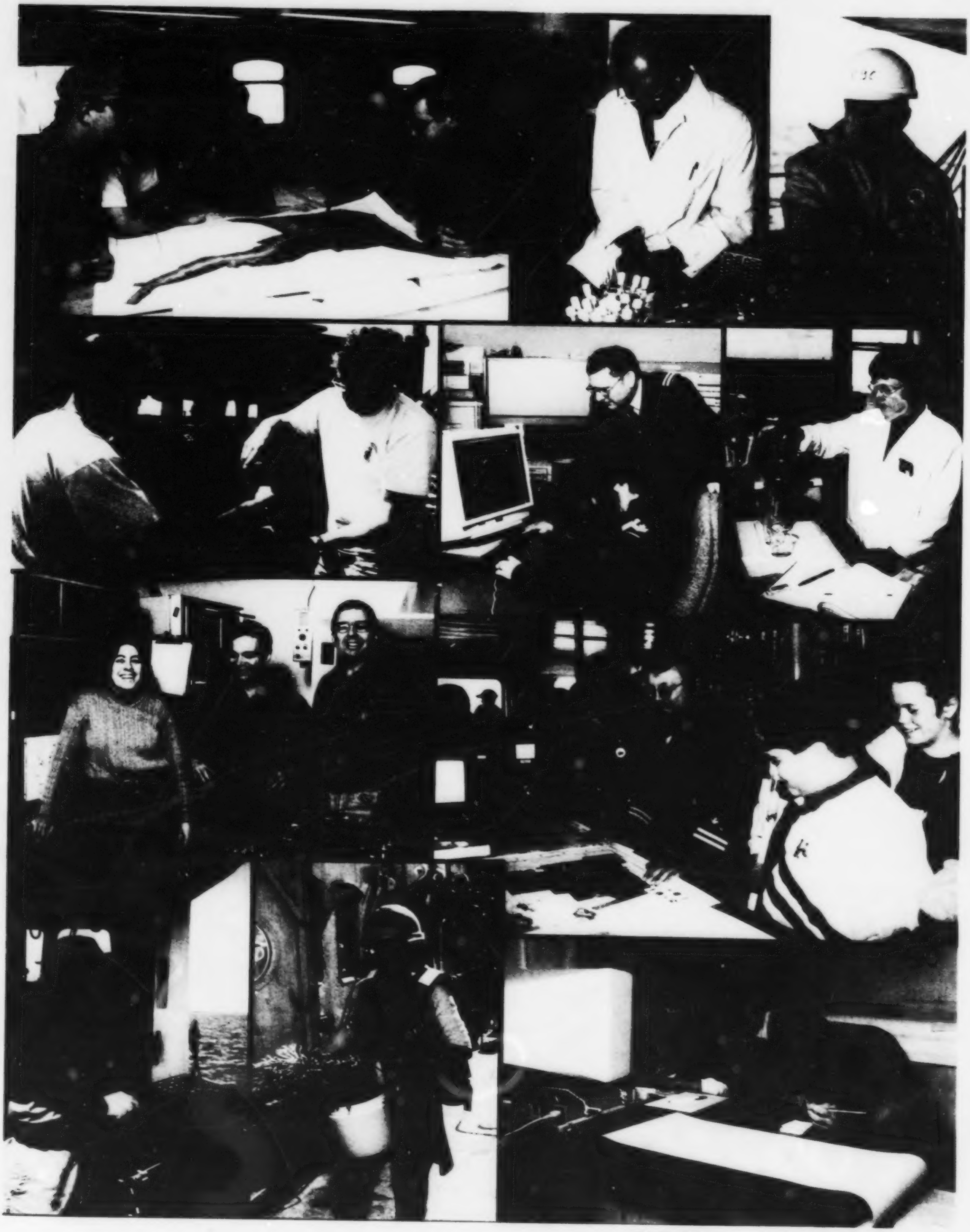
Other smaller, but important charitable events at BIO, include the sale of daffodils for the Canadian Cancer Society, and fruitcakes at Christmas time for the Multiple Sclerosis Society. A home-grown annual musical experience called the Kitchen 2 Blues Party generated food donations from its audience for the Parker Street Furniture and Food Bank in Halifax. BIO staff also helped to prepare and deliver over 550 Christmas dinners to people in need on behalf of the Parker Street Furniture and Food Bank.

The benevolence and participation of staff and retirees is one of BIO greatest assets.



Hockey teams for the staff game – December 2000.

Staff



OTHER PROGRAMS

International Ocean Colour Coordinating Group (IOCCG) - Venetia Stuart

Over the past three years, the Bedford Institute of Oceanography has been home to the Project Office of the International Ocean Colour Coordinating Group (IOCCG). Part of the mandate of this group is to promote international cooperation in the distribution, calibration and utilization of ocean-colour data from satellites launched by different countries (see IOCCG website at http://www.ioccg.org). The IOCCG also has an interest in education, especially in developing countries, and has conducted advanced ocean-colour training courses in Chile, India, Thailand and Turkey. Plans are underway to conduct further training courses in Thailand, South Africa, New Caledonia and Argentina.

The IOCCG is a relatively small group, consisting of 20 committee members from 15 different countries. These include representatives from major Space Agencies that have launched ocean-colour satellites, i.e. NASA (USA), NASDA (Japan), ESA (Europe), CNES (France), DLR (Germany) and ISRO (India), as well as experts in the field of ocean-colour research. The IOCCG is chaired by Dr. Trevor Platt, Head of Biological Oceanography at BIO, and the Project Office is staffed by Dr. Venetia Stuart and Bart Hulshof, both under contract to SCOR (Scientific Committee on Oceanic Research) in Baltimore, USA.

Currently six satellites carrying ocean-colour sensors circle the earth at a height of approximately 700 km. One of the roles of the IOCCG is to help coordinate these satellite missions, as well as to coordinate the acquisition and distribution of the data. This is accomplished through specialized IOCCG working groups, that investigate specific issues and produce technical reports providing advice for agencies, scientists and managers.

Measurements of ocean colour from space allow oceanographers to map the distribution and concentration of the pigment, chlorophyll-*a*, in the oceans. Chlorophyll-*a* is used as an index of the concentration of phytoplankton, that forms the base of the marine food chain. Global events such as El Niño have been well documented using ocean-colour data. Since phytoplankton fix carbon dioxide during photosynthesis, ocean-colour data can also be used to examine the fluxes of carbon on a global scale, which has important implications for climate change research (CO_2 is one of the major greenhouse gases contributing to global warming).

Fluctuations in pigment concentrations can also be used to provide long-term data for analysis of decadal trends in exploited fish stocks and other living marine resources. Many commercial fishing fleets use maps of ocean-colour pigment distributions to help predict the presence of fish shoals.

In addition to measuring pigment concentrations, the new generation of ocean-colour sensors can also measure the concentration of suspended particulate material (e.g. sediments) and dissolved yellow substances, which are also useful in aspects of coastal-zone management such as monitoring water quality, river runoff, sediment dynamics and coastal pollution.

Processed with SeaDAS version 3.3 using HNSG data with NRT met and ozone data

*Composite image (1-15 July, 1999) of chlorophyll-*a *distribution in the waters around the east coast of Canada, collected by NASA's SeaWiFS ocean-colour sensor. High concentrations of phytoplankton (shown in yellow/orange) are visible over Georges Bank (bottom left), historically an important fishing ground. Data processed by the Remote Sensing Unit, Biological Oceanography Section, BIO.*

Partnership for Observation of the Global Oceans (POGO)

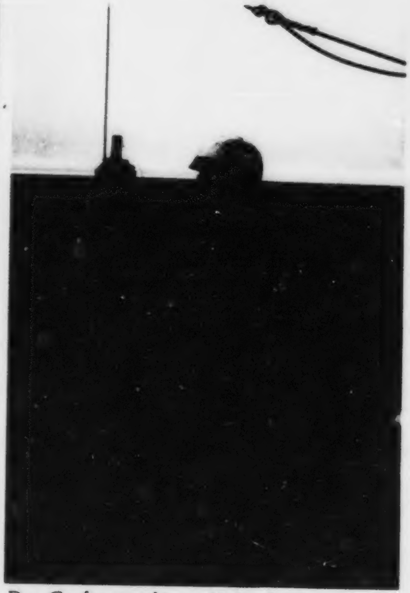
Shubha Sathyendranath

The Bedford Institute of Oceanography hosts the POGO Secretariat. POGO recently hired Dr. Shubha Sathyendranath, a long-time adjunct research scientist at BIO as its first Executive Director.

The Partnership for Observation of the Global Oceans was created in 1999 by leaders of major world oceanographic institutions to promote global oceanography, particularly the implementation of an international and integrated global oceans observing system. POGO is a partnership of oceanographic institutions that conducts ocean observations, scientific research, operational services, education, and training. They will co-ordinate their activities with other international and regional programs and organizations with an oceanographic interest.

Through joint planning and exchange of information, the global ocean community can make better use of the limited resources available. POGO does not set scientific goals, but focuses on coordination among the institutions involved and on implementation issues such as technical compatibility among observing networks, shared use of infrastructure, public outreach, and capacity building.

The oceans cover three-quarters of the Earth's surface and are fundamental to life on our planet. By facilitating collaborative partnerships, POGO helps to promote extensive and sustained observations as well as research and modeling of the oceans. POGO also encourages developing countries to participate in collecting and using environmental information for their own needs.



Don Gordon attaching a Niskin bottle.

The long-term aim of POGO is to participate in the creation and operation of an integrated global ocean strategy that addresses the information needs of decision-makers, researchers, service providers, and the public. POGO's contribution is to provide an informal forum for dialogue among leaders of key oceanographic institutions. A goal of POGO is to help integrate the observational needs of different ocean disciplines (such as ocean circulation, biology and climate) and reduce barriers between research and operational activities.

Scripps hosted the first formal meeting in early December 1999. This inaugural meeting included senior officials from 17 institutions in 12 countries. In attendance were representatives from Australia, Brazil, China, France, Germany, India, Japan, Korea, Norway, Russia, UK, the USA, the United Nations Intergovernmental Oceanographic Commission (IOC), the Scientific Committee for Oceanic Research (SCOR) of the International Council for Science (ICSU), the Committee on Earth Observation Satellites (CEOS), and several other international scientific programs. At this meeting, there was agreement on an initial work plan. This included development of an advocacy plan for observing systems, participation in processes to secure governmental commitments to fund ocean observing systems, a data interchange pilot project and establishment of a clearinghouse for information exchange among POGO members, as well as the broader community.

For further information, visit: http://www.sioworld.ucsd.edu/pogo.html

Bedford Institute of Oceanography - Oceans Association - Dale Buckley

In the summer of 1997 a group of seven former employees of the Bedford Institute of Oceanography began discussions on the formation of an association that would become a positive influence in preserving the spirit of the Institute. The first annual general meeting was held in May 1998. The initial objectives included: collecting and organizing items that would document the history of BIO, community events in oceanography, social events for association members, special activities at BIO, and a newsletter published by the association to allow former employees to stay in touch and be informed of association projects. Membership was open to all former employees of federal departments who had worked at the Bedford Institute of Oceanography and to former employees of DFO who had worked in ocean sciences at other facilities in the metropolitan area of Halifax and Dartmouth. In the fall of 1999, membership was extended to all current employees located at BIO. By the year 2000, memberships had grown to 136. The Association has recently registered under the Nova Scotia Societies Act with a formal memorandum of association and by-laws.

An initial project undertaken was to compile a complete list of all staff who had worked at BIO from its founding in 1962 until 1965. The list includes the employees' areas of specialization, organizational

BIO-OA members embark on a canal boat excursion, Midlands England, June 2000.

affiliation, and years of work at the Institute. In May of 1998 a co-venture was begun with the BIO Library to preserve paper archives and photographs that document the early history of BIO. An artifacts archive was also established with a coordinator appointed by BIO management in 2000.

In the fall of 1998, members of the Association assisted at the BIO Open House by serving as guides, presenting special lectures, and assisting in display presentations. Also in 1998, the first BIO-OA newsletter was published with several articles designed to stimulate interest in the objectives of the Association. Subsequent newsletters are now published on the web (http://fox.nstn.ca/~pitech/ BIO. News).

Social events for members have been an important part of the Association's activities. These have included two annual fall receptions on HMCS *Sackville*, winter social nights at the Owl's Club in Dartmouth, and summer picnics and barbecues at various sites. A bridge card group met at BIO during 1999 with an instructor to assist players to improve their skills at the game. The BIO-OA co-hosts the annual Christmas party. A major social event in June of 2000 was a travel adventure to England, when 11 members with family and friends travelled on some of the Midlands canals using narrow boats rented from a tourist company. Along with the beautiful scenery observed along the canals, the group enjoyed recounting adventures and misadventures over enjoyable pub meals.

Another initiative under way by BIO-OA is establishing a recognition award that will honour past and present employees of BIO who have made outstanding contributions to the Institute through cooperation and community spirit. It is anticipated that the first of these annual awards will be presented in 2001.

Summer picnic at the Srivastava residence, Dartmouth, N.S.

The Fishermen and Scientists Research Society - Kees Zwanenburg

The Fishermen and Scientists Research Society was formally established as a non-profit organization in January of 1994 after a year of pilot projects and discussions. The Society has an office at the Bedford Institute of Oceanography.

The objectives of the Society are to:

- promote effective communication between fishermen, scientists, and the general public,
- establish and maintain a network of fishermen and scientists capable of conducting collaborative research, and
- collect information relevant and necessary to the long-term sustainability of marine fisheries.

The Society was formed out of the recognition by both fishermen and scientists that each has valuable contributions to make to the effective long-term stewardship of living marine resources. A partnership based on effective communication and common goals was a necessary prerequisite to realizing this objective.

The early days involved lots of discussions in kitchens, town halls, church basements, and bait sheds to build initial bridges and trust between fishermen and scientists, to develop some common language, and to negotiate common goals. These early steps were necessary to overcome the significant mistrust that had developed between the two groups. Many fishermen felt that scientists had nothing to offer because they were not fishermen and many scientists felt that fishermen, without formal training, could not participate in scientific discussions about fish stocks. From these humble beginnings, with not much more than a willingness to talk, and a feeling that co-operation was better than confrontation, the Society evolved. It has now developed into an effective organization that brings the knowledge of fishermen into the scientific arena by agreeing on rules of information and educates scientists by making them realize the wealth of knowledge about fish and fishing that fishermen gain by experience.

The Society has over 200 members throughout Atlantic Canada. The Society manages a comprehensive annual survey of fishes on the eastern Scotian Shelf, and is involved in a wide range of research projects in collaboration with the Department of Fisheries and Oceans, non-governmental organizations

DFO Minister Dhaliwal and regional management presenting the Deputy Minister's award for partners to members of the Fishermen and Scientists Research Society.

and universities in the Region. Projects include collection of detailed information on fishing practices, catch rates, species composition of catches, fish condition factors, and information on fish diets essential to understanding their roles in marine ecosystems as a whole. The Society is also conducting studies to determine levels of lobster recruitment (the number of young lobsters produced each year), seasonal changes in lobster weights, and whether or not lobsters from different areas grow at different rates. Society members also collect information on sightings of leatherback turtles. These are only some of the projects being carried out under the auspices of the Society.

The Society also communicates its objectives, activities, and achievements in an effective manner. A newsletter is sent regularly to over 1000 subscribers nationally and internationally which details the Society's activities, results of research, and schedules of events. In 1999 a web page (http\\www.fsrs.ns.ca) was set up to provide information on the Society; it includes valuable links to other marine-related websites. This year the Society held its 7th Annual Conference and general meeting. Workshop sessions were held on lobster research, trawl impact studies, grey seal research, and ecosystem studies. Attendance exceeded 120, almost doubling last year's participation. The conference included a poster and display booth session at which the results of many of the Society's collaborative research projects were presented.

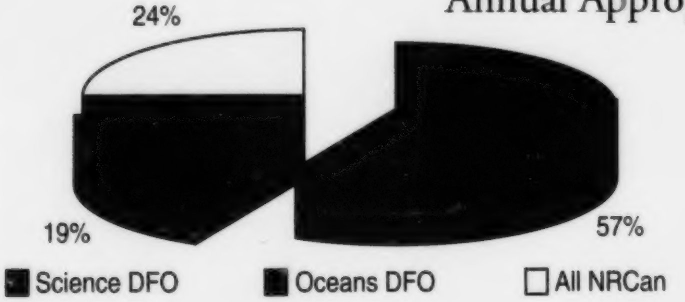
From small beginnings, the Society has developed into an organization that provides an effective forum for fishermen, scientists, and those with an interest in the long-term stewardship of marine resources to meet and deliberate in a collegial and non-confrontational manner. It has built bridges between people who should have been collaborating from the outset and who now face the challenges of the future as partners. There is still work to be done and the Society will be an effective contributor.

Carl MacDonald, Dave Gray, DFO Minister Dhaliwal and Patricia King during the award ceremony - March 2000.

FINANCIAL AND HUMAN RESOURCES INFORMATION

Where the Institute Obtains Funding and How it is Spent. Money received from government by Parliamentary Vote.

Annual Appropriation

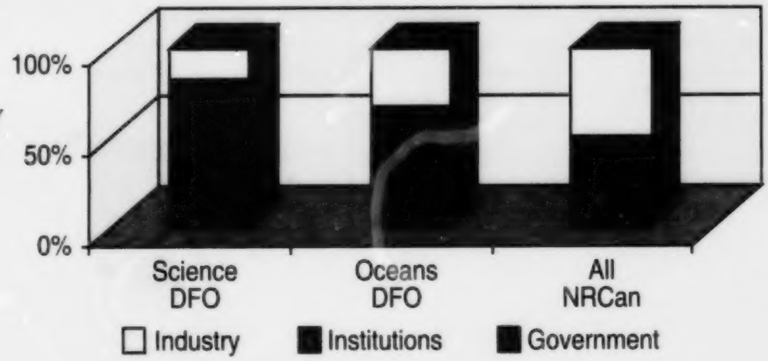


Department	Sector	Amount $(000)
DFO	Science	16,760
DFO	Oceans	5,464
NRCan	All	7,000

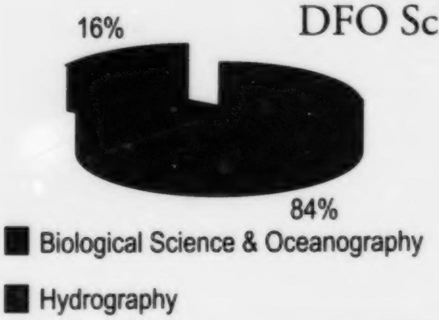
(Environment Canada and DND have staff working at BIO. The resources used by those staff members are not captured in this report.)

Other Sources of Funding

	Government $(000)	Institutions $(000)	Industry $(000)
DFO Science	7403	301	1646
DFO Oceans	900		450
NRCan All	1030		1000



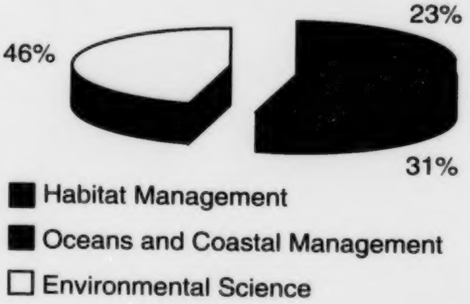
DFO Science Program Spending $(000)



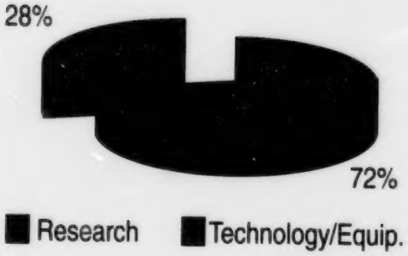
Biological Science & Oceanography	22,010
Hydrography	4,100

DFO Oceans and Environment Program Spending $(000)

DFO/Oceans Habitat Management	1,583
Oceans	2,080
Environmental Science	3,151

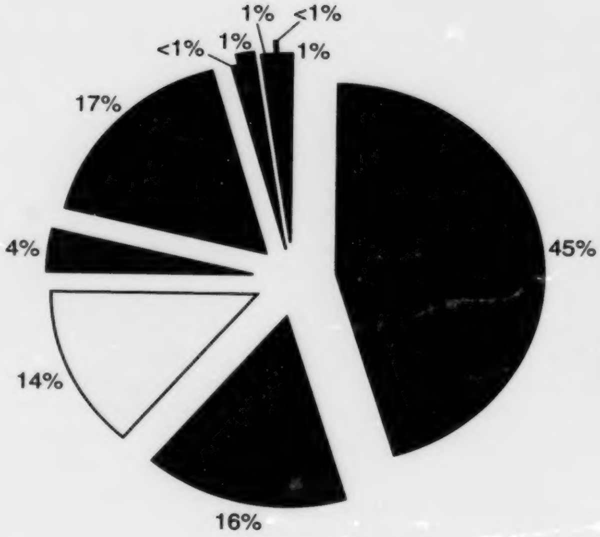


NRCan Spending $(000)



Natural Resources Canada	
Research	5,780
Technology/Equip.	2,199

BIO Staff by Department / Division



■ DFO - Science	338
■ DFO - Oceans and Environment	119
☐ DFO - Informatics & Tech Support	104
■ DFO - Library, Finance & Adm.	27
■ NRCan - GSC Atlantic	125
■ EC - Operational Laboratories	4
■ DND - Survey Office	11
■ PWGSC - Site Operations	9
■ Health Canada - Nursing Unit	2
■ Other - Research Coordination Units	8
Total	747

Source: BIO Strategic Plan - December 15, 2000

At BIO in 2000

DEPARTMENT OF NATIONAL DEFENCE

LCdr Jim Bradford
Lt(N) Scott Moody
Lt(N) Alex Barlow
CPO2 Ron MacIntosh
PO2 Claude Pageau
PO2 Nancy Kent
PO2 Leslie Guyomard
MS Jim Bartlett
MS Chris Moncrief
MS Jeff Vasseur
LS Troy Ricketts
LS Julie Daoust
LS Krista Smith

ENVIRONMENT CANADA

Christopher Craig
Kate Collins, Student
Matt Dill, Student
Bernard Richard
Mike Ripley, Student
Diane Tremblay
Jamie Young
Tim Webber, Student

FISHERIES AND OCEANS CANADA

Canadian Coast Guard – Technical Services

Mechanical & Oceanographic Systems Development
George Steeves, Supervisor
Arthur Cosgrove
Kelly Bentham
Bob Ellis
Francis Kelly
Mike LaPierre
Daniel Moffatt
Glen Morton
Neil MacKinnon
Val Pattenden
Todd Peters
Nelson Rice
Greg Siddall
Heinz Weile

Technical Maintenance
Jim Wilson, Supervisor
Gerry Dease
Don Eisner
Roger Gallant
Richard Johnson
Robbie MacGregor
Morley Wright
Mike O'Rourke
Mark Robbins

Vessel Support
Andrew Muise, Supervisor
Richard LaPierre
Stanley Myers
Steve Myers
Lloyd Oickle
Bill Preston
Dani Rippey

Science Branch

Regional Director's Office
Michael Sinclair, Director
Ann Butler
Lori Chisholm, Student
Marie Charlebois-Serdynska
Richard Eisner
Steven Fancy, Student
Dianne Geddes
Gabriela Gruber
Joni Henderson
Jasmine Marshall, Student
Sharon Morgan
Bettyann Power

Canadian Hydrographic Service
Richard MacDougall, Director
Bruce Anderson
Carol Beals
Dave Blaney
Frank Burgess
Bob Burke
Fred Carmichael
Mike Collins
Chris Coolen
Gerard Costello
Andy Craft
John Cunningham
Elizabeth Crux
Tammy Doyle
Theresa Dugas
Mike Earle
Steve Forbes
Claudine Fraser
Doug Frizzle
Jon Griffin
James Hanway
Judy Hammond
Malcolm Jay
Roger Jones
Heather Joyce
Glen King
Mike Lamplugh
Christopher LeBlanc
Kirk MacDonald
Bruce MacGowan
Grant MacLeod
Clare McCarthy
Dave McCarthy
Paul McCarthy
Dale Nicholson
Larry Norton
Stephen Nunn
Charlie O'Reilly
Nick Palmer
Richard Palmer
Paul Parks
Stephen Parsons
Ken Paul
Bob Pietrzak
Vicki Randhawa
Doug Regular
Gary Rockwell
Glenn Rodger
Dave Roop
Tom Rowsell
Chris Rozon
Betty Rumley
Mike Ruxton
Cathy Schipilow
June Senay
Alan Smith
Andrew Smith
Nick Stuifbergen
Michel Therrien
Herman Varma
Craig Zeller

Diadromous Fisheries Division
Larry Marshall, A/Manager
John Ritter*
Doug Aitken
Peter Amiro

Term and casual employees, interns, students and contractors are listed if they worked at BIO for at least four months in the year 2000.
*Retired in 2000.

Rod Bradford
Henry Caracristi
Carolyn Harvie
Phil Hubley
Eric Jefferson
Brian Jessop
Paul Leblanc
Dave Longard
Sonya Melnyk, Student
Shane O'Neil
Kimberley Robichaud-Leblanc
Karen Rutherford
Debbie Stewart
Daisy Williams

Invertebrate Fisheries Division
René Lavoie, A/Manager
Jerry Black
Maureen Butler
Patrick Carroll
Manon Cassista
Victoria Clayton
Ross Claytor
Michele Covey
Ron Duggan
Catriona Day
Ian Dempsey
John Dykens
Michael Eagles
Curtis Falls, Student
Cheryl Frail
Ken Freeman
Amanda Ginnish, Student
Lea-Anne Henry, Student
Daniel Jackson
Ellen Kenchington
Peter Koeller
Mark Lundy
Barry Macdonald
Bob Miller
Stephen Nolan
Lisa Paul, Student
Doug Pezzack
Alan Reeves
Ginette Robert
Dale Roddick
Bob Semple
Glyn Sharp
Stephen Smith
Amy Thompson, Student
John Tremblay
Benedikte Vercaemer
Cathy Wentzell

Marine Fish Division
Wayne Stobo, A/Manager
Susan Baker
Diane Beanlands
Don Bowen
Bob Branton
Alida Bundy
Steve Campana
Peter Comeau
Paul Fanning
Wanda Farrell
Mark Fowler
Ken Frank
Caihong Fu
Ralph Halliday
Lei Harris
Peter Hurley
Bill MacEachern
Linda Marks
Jim McMillan
Jeff Mcruer
Bob Mohn
Jim Reid
Mark Showell
Jim Simon
Nancy Stobo
Scott Wilson
Gerry Young
Kees Zwanenburg

Ocean Sciences Division
Allyn Clarke, A/Manager
Pat Williams
Barbie Henneberry

Biological Oceanography
Trevor Platt, Head
Jeffrey Anning
Florence Berreville, Student
Heather Bouman, Student
John Bugden
Carla Caverhill
Paul Dickie
Andrew Edwards, PDF
Gretchen Fitzgerald, Student
Cesar Fuentes-Yaco, PDF
Lee Geddes
Rajashree Gouda, Student
Leslie Harris
Glen Harrison
Erica Head
Edward Horne
Brian Irwin
Mary Kennedy
Paul Kepkay
Marilyn Landry
William Li
Heidi Maass
Markus Pahlow, PDF
Kevin Pauley
Linda Payzant
Catherine Porter
Douglas Sameoto
Dawn Shepperd, Student
Jeffrey Spry
Alain Vezina
Louisa Watts, PDF
George White

Coastal Ocean Science
Peter Smith, Head
Gary Bugden
Sandy Burtch
Jason Chaffe
Joel Chassé
Brendan DeTracey
Ken Drinkwater
Yuri Geshelin
Dave Greenberg
Guoqi Han
Charles Hannah
Don Lawrence
Bob Lively
John Loder
Sean Oakey
Ingrid Peterson
Brian Petrie
Liam Petrie
Roger Pettipas
Simon Prinsenberg
Victor Soukhovstev
Charles Tang
Ted Tedford
Tina VanderBaaren
Tom Yao
Chou Wang
Zhigang Xu

Ocean Circulation
Michel Mitchell, A/Head
Robert Anderson
Karen Atkinson
Nancy Chen
Sharon Gillam-Locke
Blair Greenan
Douglas Gregory

Term and casual employees, interns, students and contractors are listed if they worked at BIO for at least four months in the year 2000.
*Retired in 2000.

Helen Hayden
Ross Hendry
Anthony Isenor
Jeff Jackson
Peter Jones
David Kellow
Neil Oakey
William Perrie
Marion Smith
Brenda Topliss
Bash Toulany
Dan Wright
Frank Zemlyak

Ocean Physics
Alex Herman, Head
Brian Beanlands
Don Belliveau
Norman Cochrane
Katherine Collier
John Conrod
George Fowler
Jim Hamilton
Randy King
George States
Ted Phillips
Scott Young

Technical Operations
Dave McKeown, Head
Larry Bellefontaine
Rick Boyce
Bert Hartling
Bruce Nickerson
Bob Ryan
Murray Scotney

Maritimes Regional Advisory Process (RAP)
Bob O'Boyle, Coordinator
Valerie Myra

Maritimes Aquatic Species at Risk Office
John S. Loch, Manager
Bob Barnes
Jerry Conway
Lynn Cullen

Oceans and Environment Branch

Regional Director's Office
Faith Scattolon, Director
Jane Avery
Melissa McDonald
Ted Potter

Habitat Management Division
Brian Thompson, Manager
Brooke Cook
Joey Crocker
Rick Devine
Joy Dube
Joanne Gough
Anita Hamilton
Tony Henderson
Craig Hominick
Brian Jollymore
Jim Leadbetter
Jack Leeman
Melanie MacLean
Shayne McQuaid
Marci Penney-Ferguson
Jim Ross
Carol Sampson
Carol Simmons
Reg Sweeney
Phil Zamora

Marine Environmental Sciences Division
Paul Keizer, Manager
Jim Abriel
Byron Amirault
Debbie Anderson
Carol Anstey
Shelley Armsworthy
Robert Benjamin
Paul Boudreau
Cynthia Bourbonnais
Victoria Burdett-Coutts, Student
Chiu Chou
Pierre Clement
Peter Cranford
John Dalziel
Elaine Desnoyers, Student
René Doucett
Grazyna Folwarczna
Don Gordon
Gareth Harding
Barry Hargrave
Jocelyn Hellou
Sheri Johnson, Student
Thomas King
Brent Law
Ken Lee
Jim Leonard
Kevin MacIsaac
Tim Milligan
John Moffatt
Rick Nelson
Sherry Niven
Lisa Paon
Georgina Phillips
Jayne Roma, Intern
Sylvie Roy
Sylvia Rumbolt
Heidi Schaefer
Sheila Shellnut
Kimberly Sheppard
Judy Simms
John Smith
Efren Sta.Marie, Visiting Scientist
Sean Steller
Andrew Stewart
Peter Strain
Peter Vass
Douglas Willis*
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Recognition

BIO staff wish to recognize the contribution and support provided by the Captains and crew of Canadian Coast Guard vessels tasked to assist BIO-based research.

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*Retired in 2000.

In Memoriam

Fred Cluney - June 1998

Fred began his career with Fisheries & Oceans on June 7, 1982. He was hired as a plumber working at the Bedford Institute of Oceanography. After a few years working inside the facility he decided to take the opportunity to work outdoors doing grounds maintenance. With the start of the property management agreement between Fisheries & Oceans and PWGSC his position along with all maintenance jobs were transferred to PWGSC in 1993. His job continued to be in charge of grounds maintenance and the sewage treatment plant at the facility. He was well known at BIO and recognized by wearing his 'navy toque' during all seasons even in the heat of summer! Fred took tremendous pride in the appearance and upkeep of the grounds at BIO and was instrumental in the creation of the new walkway, landscaping and flowerbeds between the rear parking lot and the Sea Pavilion. In recognition and remembrance of the dedicated service that Fred provided at BIO, the walkway from the rear parking lot to the Sea Pavilion was commemorated as Cluney Lane on July 13, 1999. His family, and many colleagues attended the dedication ceremony.

Fred lost his life at sea on June 30, 1998 during a recreational fishing trip.

Katherine M. Ellis - July 1998

Kathy Ellis (M.Sc., Dalhousie University) joined the Chemical Oceanography Division at BIO in 1978. She established an environmental radioactivity laboratory at BIO and helped set up a program to evaluate environmental impacts associated with the release of radioactivity into the Bay of Fundy from the Point Lepreau, N.B. nuclear reactor. In 1983, she began a long and eventful career in arctic studies with a month long stay at the CESAR Ice Station located about 300 km south of the North Pole. In 1984 and 1991 she helped organize Canadian-Danish expeditions to Thule, Greenland to study the marine contamination resulting from nuclear weapons that were destroyed when a US B-52 bomber crashed on the ice in 1968. One of her most exciting arctic adventures was her participation in a Russian cruise in 1993 to the previously top-secret, but then deserted nuclear test site at Chernaya Bay, on the island of Novaya Zemlya in the Barents Sea. During this expedition she led a team that recovered sediment cores revealing high plutonium levels from underwater nuclear weapons tests carried out by the Soviet Union in the 1950s. Kathy also led the marine radioactivity team during the historic Arctic Ocean Section cruise that involved the transit of the CSS Louis St. Laurent across the Arctic Ocean via the North Pole in 1994.

Kathy had a deep commitment to the principles of high quality scientific research and the communication of this knowledge to students and professionals in developing nations. This resulted in numerous trips to China and more recently to Turkey and the Phillipines to participate in collaborative studies and training workshops.

Peter John Schwinghamer – May 1999

Dr. Peter Schwinghamer received his Ph.D. from Dalhousie University in 1981 and joined the Marine Ecology Laboratory at BIO that same year. During his Ph.D. program, Peter developed hypotheses on the biomass-size structure of benthic communities that has been fundamental in bringing benthic community analysis into the mainstream of ecological science. His post-doctoral studies at BIO concentrated on developing improved methods for extracting and processing microfauna and meiofauna from marine sediments. In 1987, Peter transferred to the Northwest Atlantic Fisheries Centre (St. John's, NF), where he established a new multi-disciplinary program in benthic ecology. Starting in 1990, Peter applied his broad experience in benthic ecology to the complex issue of the effects of mobile fishing gear on benthic habitat and communities. Working with colleagues at BIO and in industry, he helped develop a suite of new and improved instruments for sensing and sampling benthic habitat and communities on offshore fishing banks. His most significant contribution to this experiment was the application of high-resolution acoustics and chaos theory to understand the effects of trawling on sediment habitat structure. In the midst of these investigations, in 1991, Peter was diagnosed with a brain tumour. He underwent surgery, and made a remarkable recovery to continue his scientific career for a number of years. In 1995, Peter returned to BIO where he worked until he was forced to retire early due to his medical condition.

Peter passed away peacefully at home in Halifax on May 22, 1999 at the age of 52 after a long and courageous battle. Peter Schwinghamer was considered to be a world leader in benthic ecology. One can only imagine what further contributions he could have made in this field if his career had not been ended prematurely.

Nicholas Prouse - May 2000

Nick Prouse was one of eight graduates of the first class of Marine Biology Program at Guelph University. As a summer student in 1970 he worked with the Department studying distribution and spawning behavior of mackerel in coastal waters of Nova Scotia. The following year, he joined a team studying ecosystem structure and dynamics of productivity in Petpeswick Inlet. Following graduation in 1971, he was recruited to the Marine Ecology Laboratory at the BIO investigating the impacts of the oil spill from the Arrow that sank in Chedabucto Bay in 1970.

During his career Nick's research activities were diverse in nature. They included the assessment of impacts of oil pollution on plankton and benthic fauna, studies of pesticide biomagnification in lower trophic level organisms, evaluation of organic enrichment effects in Halifax Harbour and assessment of potential tidal power impacts on intertidal ecosystems in the upper Bay of Fundy. In 1987, Nick was assigned to work with a group of chemists studying contaminants in commercial fish populations. This move recognized his unique blend of knowledge and experience in inter-disciplinary research. He developed an interest in the endocrin disrupting effects of various chemicals, which led to his investigation of the role of anti-foulants used on ships in altering the sexual development in intertidal snails. This research was a prime example Nick's ability to tackle cross-disciplinary issues.

Nick died in May 2000 after a long and courageous battle with esophageal cancer.

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Chart No. 4905. Cape Tormentine to/à West Point. NEWEDN.

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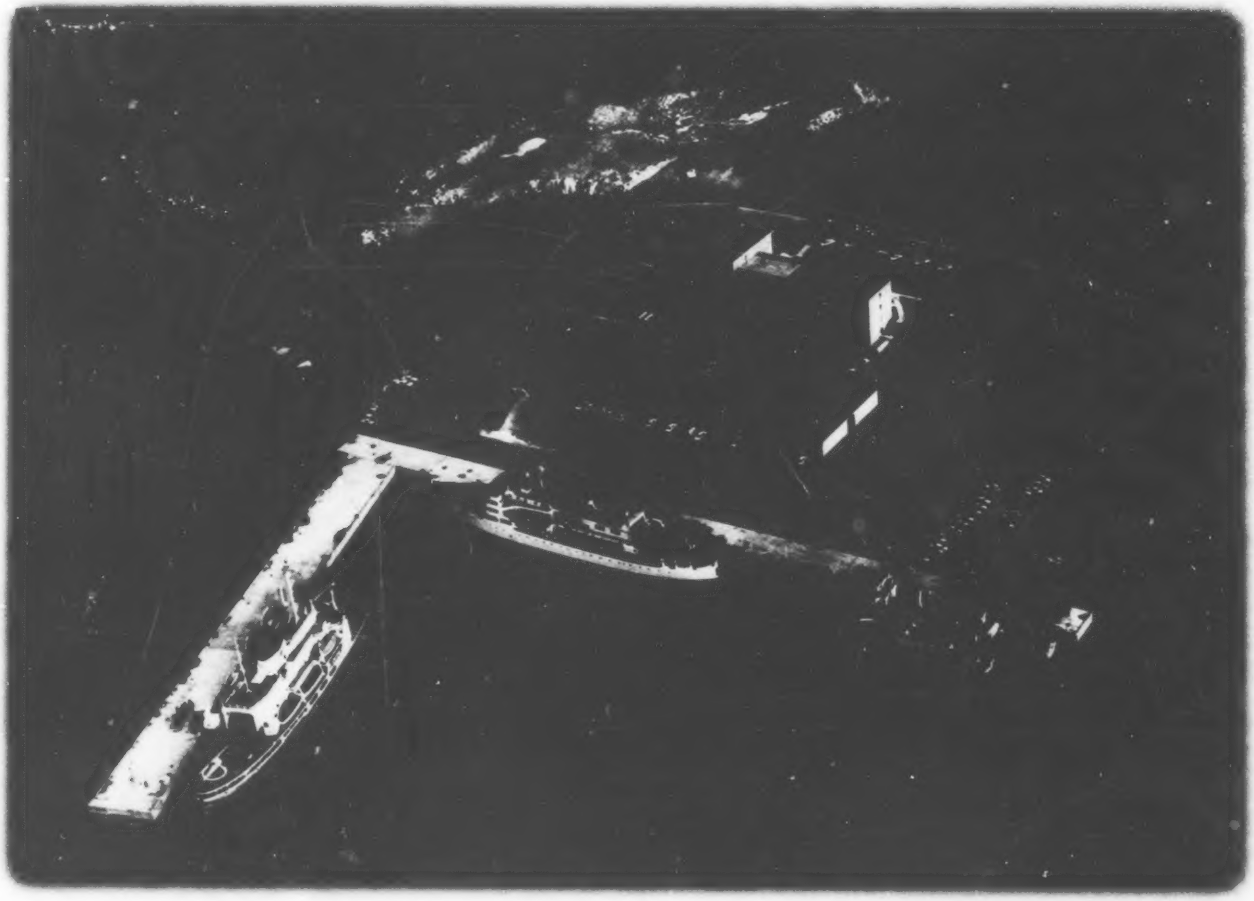

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